



Description of Existing Data for Integrated Landscape Monitoring in the Puget Sound Basin, Washington



Puget Sound Integrated Landscape Monitoring Study Area

Open-File Report 2008-1308

U.S. Department of the Interior
U.S. Geological Survey

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By Danielle P. Aiello, Alicia Torregrosa, Allyson L. Jason, Tracy L. Fuentes and Edward G. Josberger

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List of Acronyms

CTD	Conductivity-temperature-depth
CWMA	Cooperative Weed Management Area (Nisqually Watershed)
DLG	Digital line graph
DRG	Digital raster graphic
Ecology	Washington State Department of Ecology
EMAP	Environmental Monitoring and Assessment Program
ESRI	Environmental Systems Research Institute
FIA	Forest Inventory and Analysis (USFS)
FIPS	Federal Information Processing Standards
GCS	Geographic coordinate system
GIO	Geospatial Information Office (USGS)
GNIS	Geographic Names Information System
GPNF	Gifford Pinchot National Forest
GPS	Global Positioning Systems

HUC	Hydrologic unit code
ILM	Integrated Landscape Monitoring
IMW	Intensively Monitored Watersheds
LiDAR	Light Detection and Ranging
MLLW	Mean Low Low Water
MPA	Marine Protected Area
MSS	Multispectral Scanner
NAIP	National Agriculture Imagery Program
NALC	North American Landscape Characterization
NASA	National Aeronautics and Space Administration
NAWMA	North American Weed Mapping Standards
NDMPL	Non-Department of Natural Resources Major Public Lands
NDVI	Normalized difference vegetation index
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRIS	Natural Resource Inventory System (USFS)
NWIFC	Northwest Indian Fisheries Commission
OSU	Oregon State University
PNW	Pacific Northwest
PRISM	Puget Sound Regional Synthesis Model (UW)
PRISM Group	Parameter elevation Regressions on Independent Slopes Model (OSU)
PS	Puget Sound
PSAMP	Puget Sound Assessment and Monitoring Program
PSILM	Puget Sound Integrated Landscape Monitoring
PSLC	Puget Sound LiDAR Consortium
PSMFC	Pacific States Marine Fisheries Commission
SaSI	Salmonid Stock Inventory
SNOTEL	SNOWpack TELemetry
SRFB	Salmon Recovery Funding Board
SRSC	Skagit River System Cooperative
SSHAP	Salmon and Steelhead Habitat Inventory and Assessment Project
SVMP	Submerged Vegetation Monitoring Project
URL	Uniform Resource Locator
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
UW	University of Washington
WA DNR	Washington State Department of Natural Resources
WA DOH	Washington State Department of Health
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation

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Introduction

This report summarizes existing geospatial data and monitoring programs for the Puget Sound Basin in northwestern Washington. This information was assembled as a preliminary data-development task for the U.S. Geological Survey (USGS) Puget Sound Integrated Landscape Monitoring (PSILM) pilot project. The PSILM project seeks to support natural resource decision-making by developing a “whole system” approach that links ecological processes at the landscape level to the local level (Benjamin and others, 2008). Part of this effort will include building the capacity to provide cumulative information about impacts that cross jurisdictional and regulatory boundaries, such as cumulative effects of land-cover change and shoreline modification, or region-wide responses to climate change.

The PSILM project study area is defined as the 23 HUC-8 (hydrologic unit code) catchments that comprise the watersheds that drain into Puget Sound and their near-shore environments. The study area includes 13 counties and more than four million people. One goal of the PSILM geospatial database is to integrate spatial data collected at multiple scales across the Puget Sound Basin marine and terrestrial landscape.

The PSILM work plan specifies an iterative process that alternates between tasks associated with data development and tasks associated with research or strategy development. For example, an initial work-plan goal was to delineate the study area boundary. Geospatial data required to address this task included data from ecological regions, watersheds, jurisdictions, and other boundaries. This assemblage of data provided the basis for identifying larger research issues and delineating the study-area boundary based on these research needs. Once the study-area boundary was agreed upon, the next iteration

between data development and research activities was guided by questions about data availability, data extent, data abundance, and data types.

This report is not intended as an exhaustive compilation of all available geospatial data, rather, it is a collection of information about geospatial data that can be used to help answer the suite of questions posed after the study-area boundary was defined. This information will also be useful to the PSILM team for future project tasks, such as assessing monitoring gaps, exploring monitoring-design strategies, identifying and deriving landscape indicators and metrics, and visual geographic communication.

The two main geospatial data types referenced in this report, base-reference layers and monitoring data, originated from numerous and varied sources. In addition to collecting information and metadata about the base-reference layers, the data also were collected for project needs, such as developing maps for visual communication among team members and with outside groups. In contrast, only information about the data was typically required for the monitoring data. The information on base-reference layers and monitoring data included in this report is only as detailed as what was readily available from the sources themselves. Although this report may appear to lack consistency between data records, the varying degree of details contained in this report are merely a reflection of varying source detail.

This compilation is merely a beginning. All data listed also are being catalogued in spreadsheets and knowledge-management systems. Our efforts are continual as we develop a geospatial catalog for the PSILM pilot project.

Base Data

Orthoimagery

The PSILM project's orthoimagery catalog is collected from several sources at multiple scales and across several spatial extents (table 1). The first three datasets describe imagery with basin-wide coverage, followed by county- (fig. 1) and regional-imagery datasets.

Table 1. Orthoimagery at-a-glance, Puget Sound Integrated Landscape Monitoring (PSILM) catalog.

	Layer name	Imagery date	Coverage	Spatial extent	Source
A.	NAIP imagery	June-August 2006	Statewide	1	USDA
	NAIP Compressed County Mosaics	June-August 2006	Statewide	1	USDA

	Layer name	Imagery date	Coverage	Spatial extent	Source
	Statewide (derived from NAIP)	June-August 2006	Statewide	1	USDA
B.	Landsat Mosaic 1990, N-10-45	1990	Puget Sound Basin	1	USGS
C.	NALC Triplicates	1970, 80, 90 Summer 2003;	Puget Sound Basin	1	USGS
D.	Thurston County	Summer 2006	Countywide	1	Thurston County
E.	Pierce County	Summer 2005	Excludes USFS and military lands	0	Pierce County
F.	King County	Summer 2007	Countywide	0	King County
G.	Kitsap County	Summer 2007	Countywide	0	Kitsap County
H.	Seattle-Tacoma urban area	June-July 2002	Defined urban area (Everett to Tacoma)	0	USGS
I.	Snohomish County	2005	Excludes USFS lands	0	Snohomish County
	Snohomish County	May-June 2007	Excludes USFS lands	0	Snohomish County

Imagery date, data acquisition date; 1, full spatial extent; 0, partial spatial extent; NAIP, National Agriculture Imagery

Program; USDA, U.S. Department of Agriculture; USGS, U.S. Geological Survey; USFS, U.S. Forest Service.



Figure 1. Map showing counties in the Puget Sound Basin study area, Washington. Seattle and Tacoma, Washington are shown for spatial reference for the urban-imagery coverage in that region.

Basin-wide Imagery

The following datasets describe orthoimagery acquired at Puget Sound Basin-wide scale.

National Agriculture Imagery Program (NAIP)—2006

NAIP, run by the U.S. Department of Agriculture (USDA), produces an annual coverage of the continental U.S. during the agricultural growing seasons. The NAIP orthophotography is available at two resolutions, 18-inch and 1-meter, as quarter-quad tiles (fig. 2), or county mosaics. The natural-color

imagery for Washington State was acquired in June, July, and August 2006. The 1-meter coverage for the Puget Sound Basin focus area is made up of 1,450 quarter-quad tiles. These tiles have a UTM projection, are available in GeoTIFF format, and total 190 MB.



Figure 2. Map of National Agriculture Imagery Program full-state, 1-meter coverage, Washington.

Landsat Mosaic—1990

The 1990 Landsat mosaic image (fig. 3) was produced by the Earth Satellite Corporation under contract to the National Aeronautics and Space Administration (NASA) through the Scientific Data Purchase Program. The USGS EROS Data Center, which serves as the National Satellite Land Remote Sensing Data Archive, supported the development of this product by providing the raw imagery. The images were compressed by using the MrSID (Multi-Resolution Seamless Image Database) compression algorithm from LizardTech, Inc.

The Landsat Mosaics were developed primarily from data collected by the Landsat 4 and Landsat 5 satellites. This historical imagery provides a record of Earth around 1990. The image, which covers half of Washington State, is spatially referenced to the WGS84 UTM Zone 10N in two formats: MrSID (136 MB) and IMAGINE (1.2 GB).

Other available Landsat data for the Puget Sound Basin can be found online at the USGS EarthExplorer and GloVis Web sites (<http://earthexplorer.usgs.gov> and <http://glovis.usgs.gov/>). Other satellite data can be accessed from the NASA Distributed Active Archive Centers (DAACs) for Earth Observation Sensors (<http://nasascience.nasa.gov/earth-science/earth-science-data-centers> and <http://nasascience.nasa.gov/earth-science/earth-science-data-centers/land-processes-daac-lp-daac>). These data include MODIS and ASTER imagery.

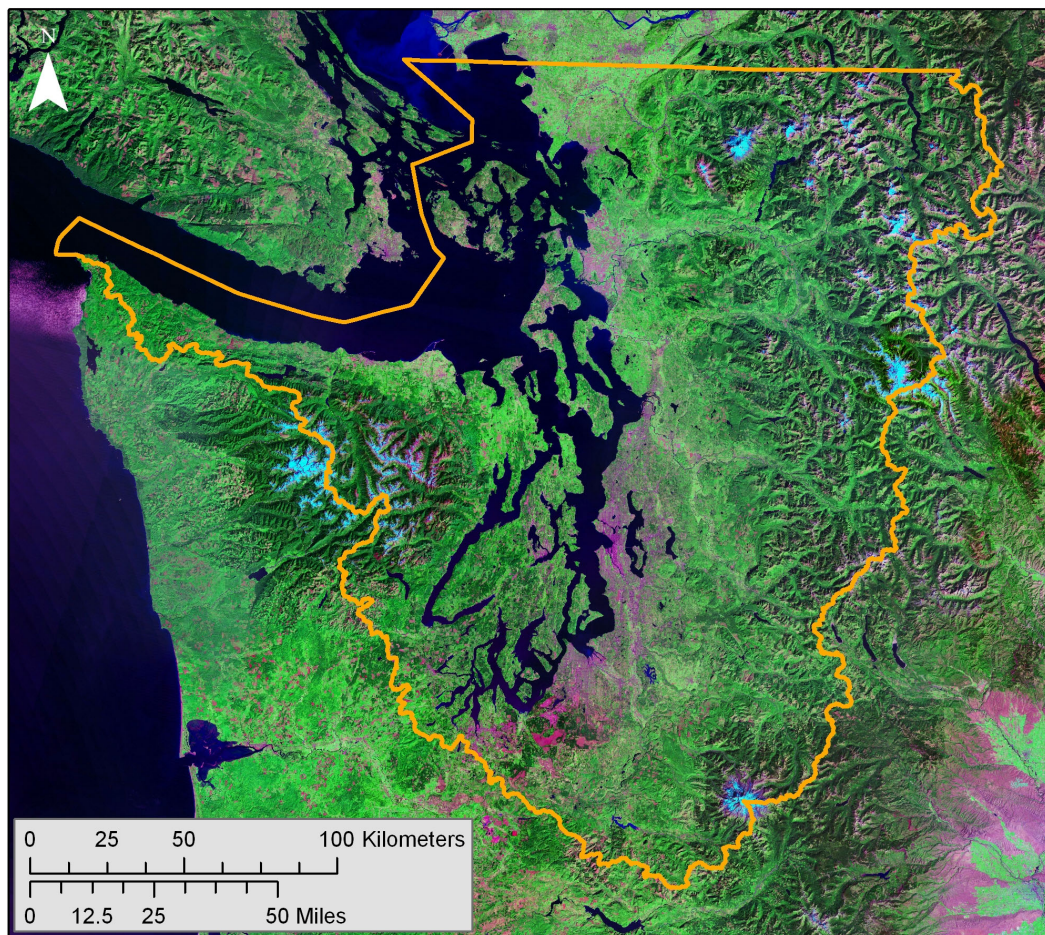


Figure 3. Map showing the Puget Sound Basin boundary in orange overlaid on the 1990 Landsat imagery mosaic.

North American Landscape Characterization (NALC) Triplicates

The NALC dataset includes multispectral scanner (MSS) Landsat images from three decades: 1970, 1980, and 1990 for the U.S. and Mexico. Average acquisition dates are 1973, 1986, and 1991. The NALC triplicates have a UTM projection and a 60-meter pixel size.

1970s image contains 5 bands: MSS bands 1 through 4 and a pixel-identity image/band. All the 1980s and 1990s images contain 6 bands: MSS bands 1 through 4, NDVI, and a pixel-identify image/band. NALC data can be searched, downloaded, and ordered through EarthExplorer or GloVis (fig. 4).

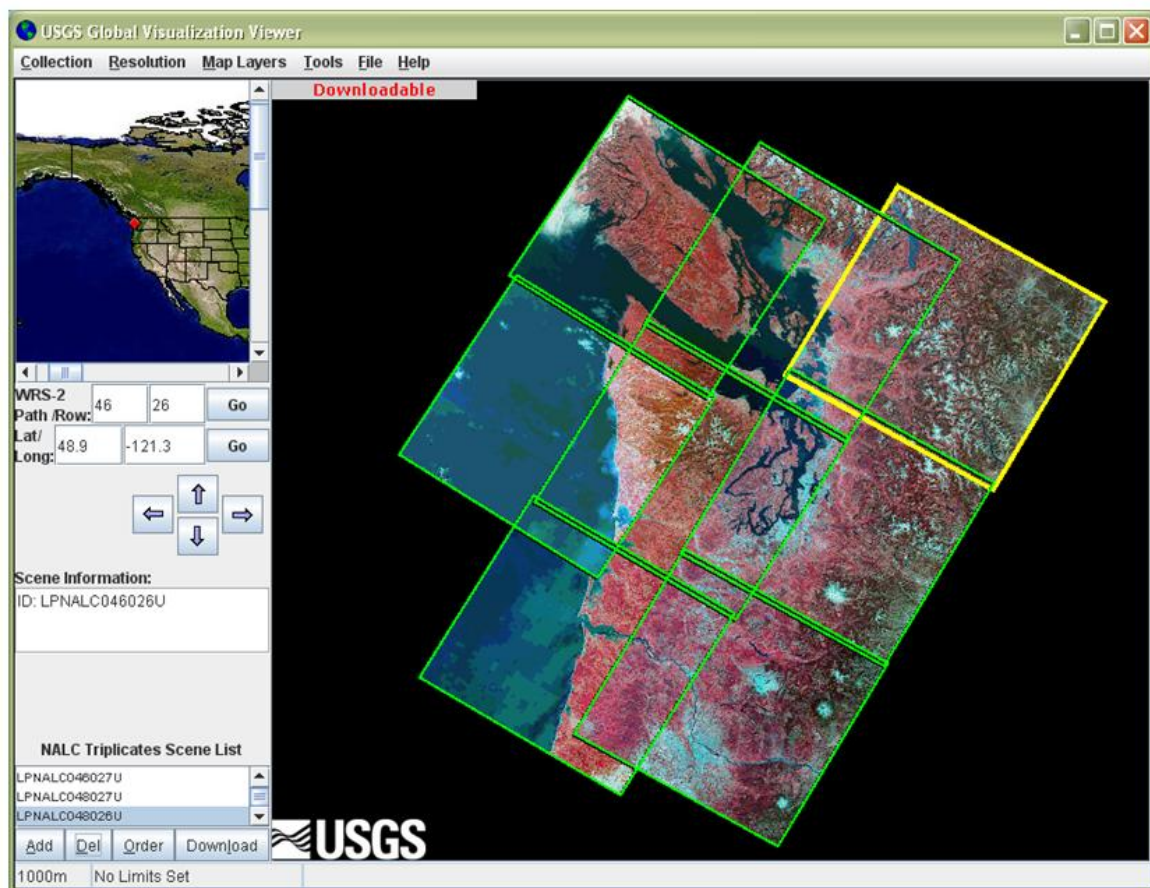


Figure 4. Screen capture of path and rows of North American Landscape Characterization (NALC) triplicates for the Puget Sound Basin, Washington from the GloVis Viewer.

County-Wide Imagery

The following datasets describe orthoimagery data collected from county-government initiatives and local regions (for example, Seattle-Tacoma) within the Puget Sound Basin that do not have basin-wide coverage. These data are handled by the USGS Geospatial Liaison for Washington State through the USGS Geospatial Information Office (GIO). This section includes only data that is relevant for the purposes of this study and does not constitute a complete list of available orthoimagery for counties or regions within the Puget Sound Basin. Besides what was collected for this project, some other orthoimagery datasets are mentioned in the text.

Thurston County—2005

The Thurston GeoData Center (TGC) acquired full-county orthophotography coverage in 2005 (fig. 5). The 18-inch-pixel resolution color photos are from a September 2005 flight, are in a state plane projection, and total 325GB in GeoTIFF format.

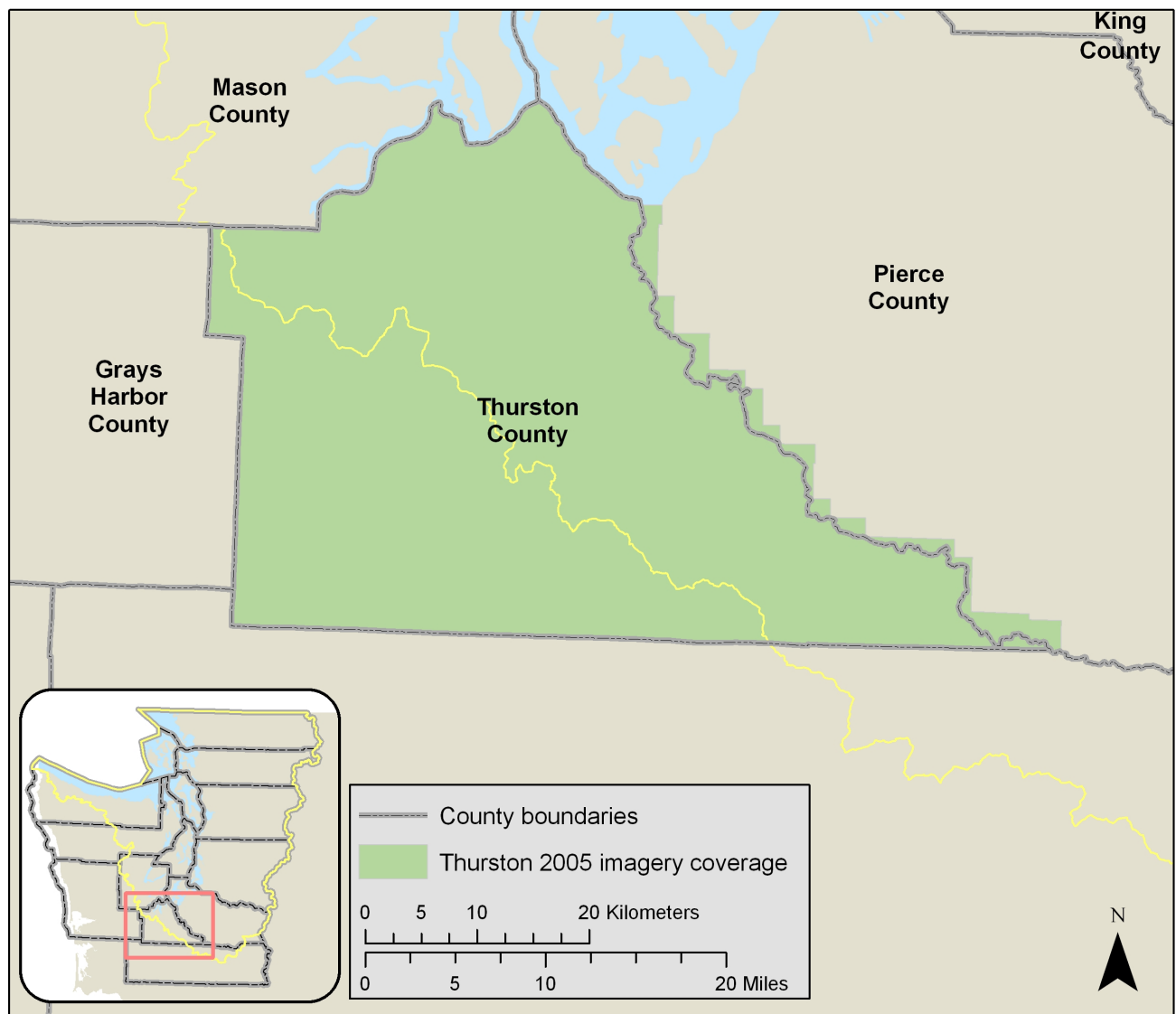


Figure 5. Map of the Thurston County, Washington 2005 imagery coverage.

Pierce County—2005

Pierce County has been acquiring orthophoto data since 1998 and is currently on a 3-year update cycle. The most recent imagery was acquired in June-July 2005 (fig. 6). Areas that are not covered by the 2005 imagery include U.S. Forest Service (USFS) and military lands. The 1-foot Pierce County imagery in GeoTIFF format are in a state plane projection and total 280 GB.

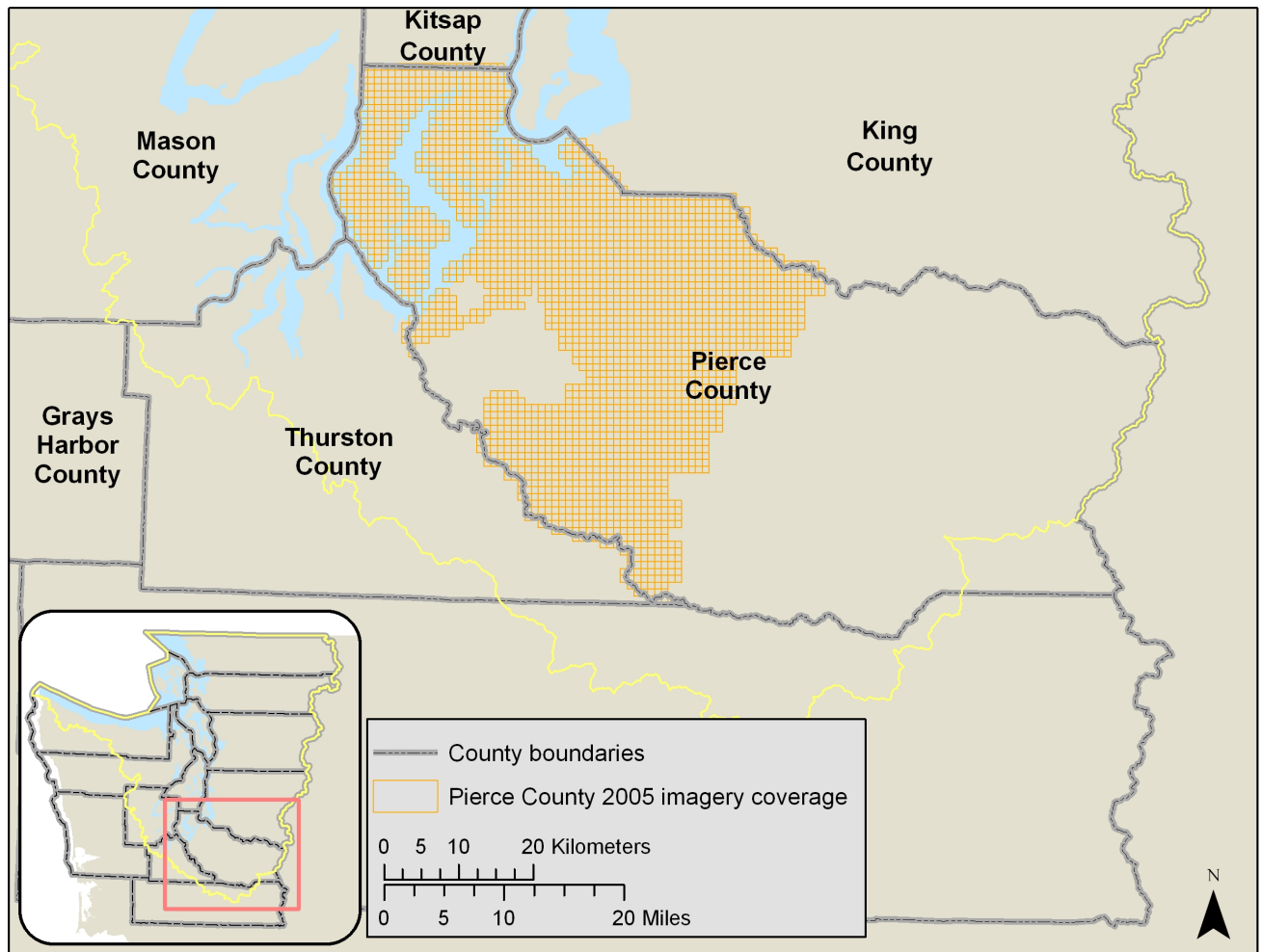


Figure 6. Map of the Pierce County, Washington 2005 imagery coverage.

F. King County—2007

King County natural-color, July 2007, orthoimagery covers the western, urbanized, portion of the county with a 6-inch resolution and covers the east, rural portion of the county with a 1-foot resolution (fig. 7). Imagery are in MRSID format and a Lambert conformal-conic projection. King County 2007 Orthoimagery metadata is available online

(http://www.metrokc.gov/gis/sdc/raster/ortho/Ortho_Data.htm#2007KC_Nat).

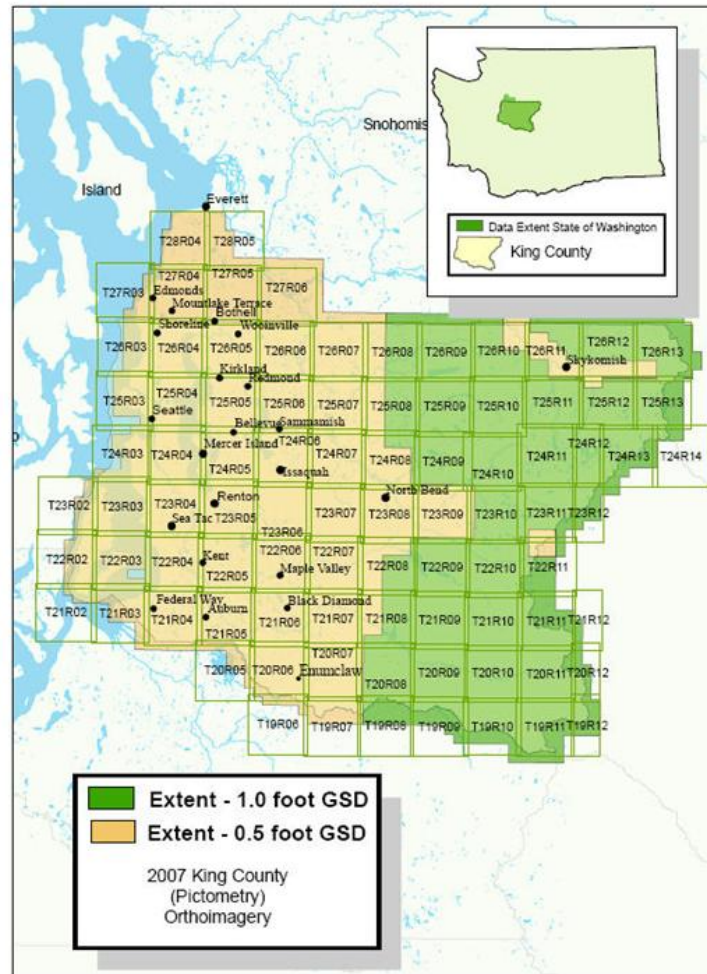


Figure 7. Map of 2007 King County, Washington imagery coverage (Source: King County).

Kitsap County—2007

Kitsap County 2007 orthoimagery covers Kitsap County with 1-foot resolution, with a 6-inch coverage also covering the northern portion of the county (fig. 8). The natural-color digital orthophoto imagery is available in TIFF and MrSID formats, and the projection is not known at this time.

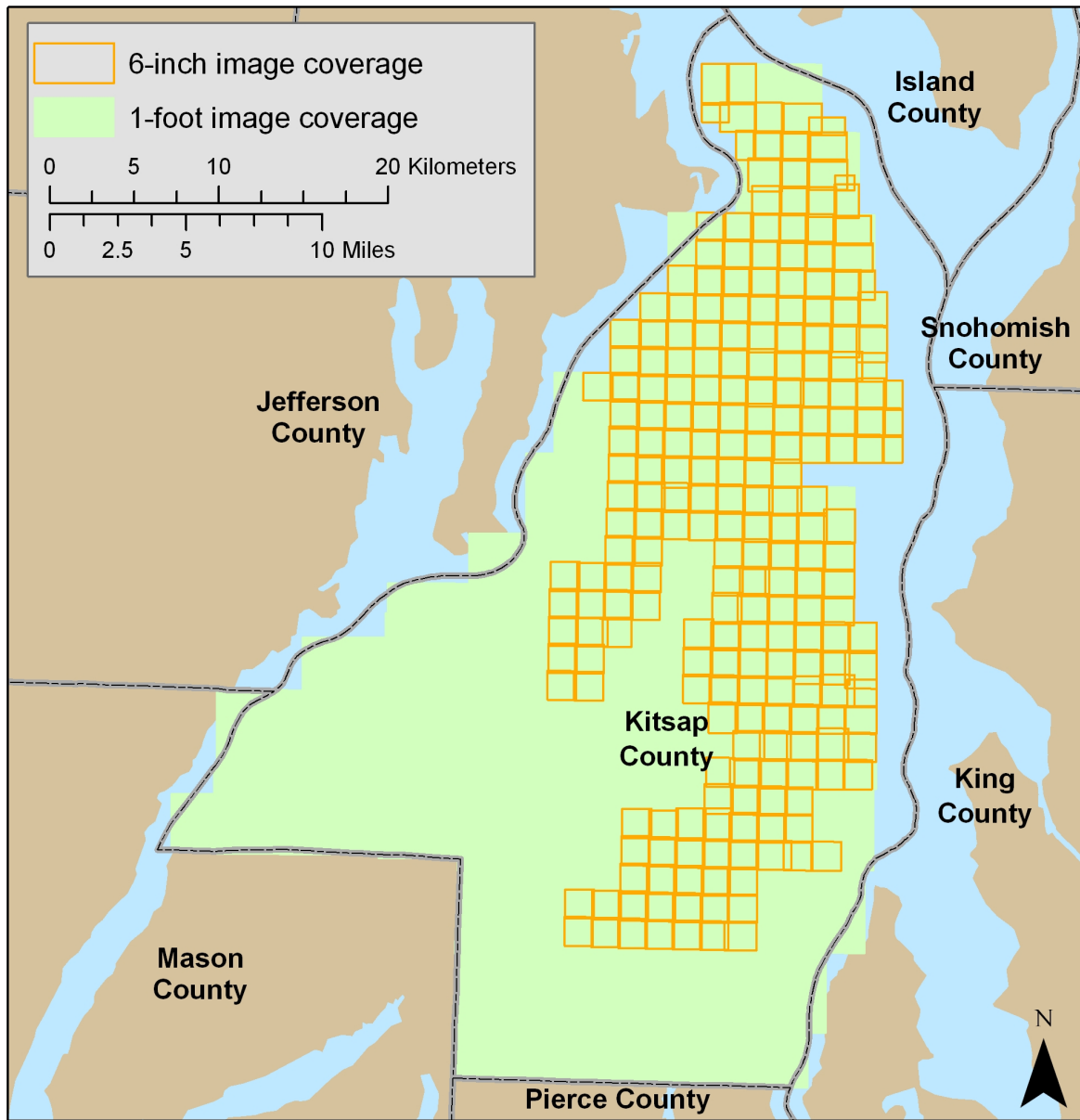


Figure 8. Map of Kitsap County, Washington 2007 imagery coverage.

Seattle-Tacoma Urban Area—2002

This imagery was provided to King County through the USGS. These data were acquired in June 2002 to produce natural-color ortho-imagery coverage of the Seattle-Tacoma Area (fig. 9). King County reprojected the image files to WA State Plane North. The 1-foot imagery in GeoTIFF format totals 135 GB.

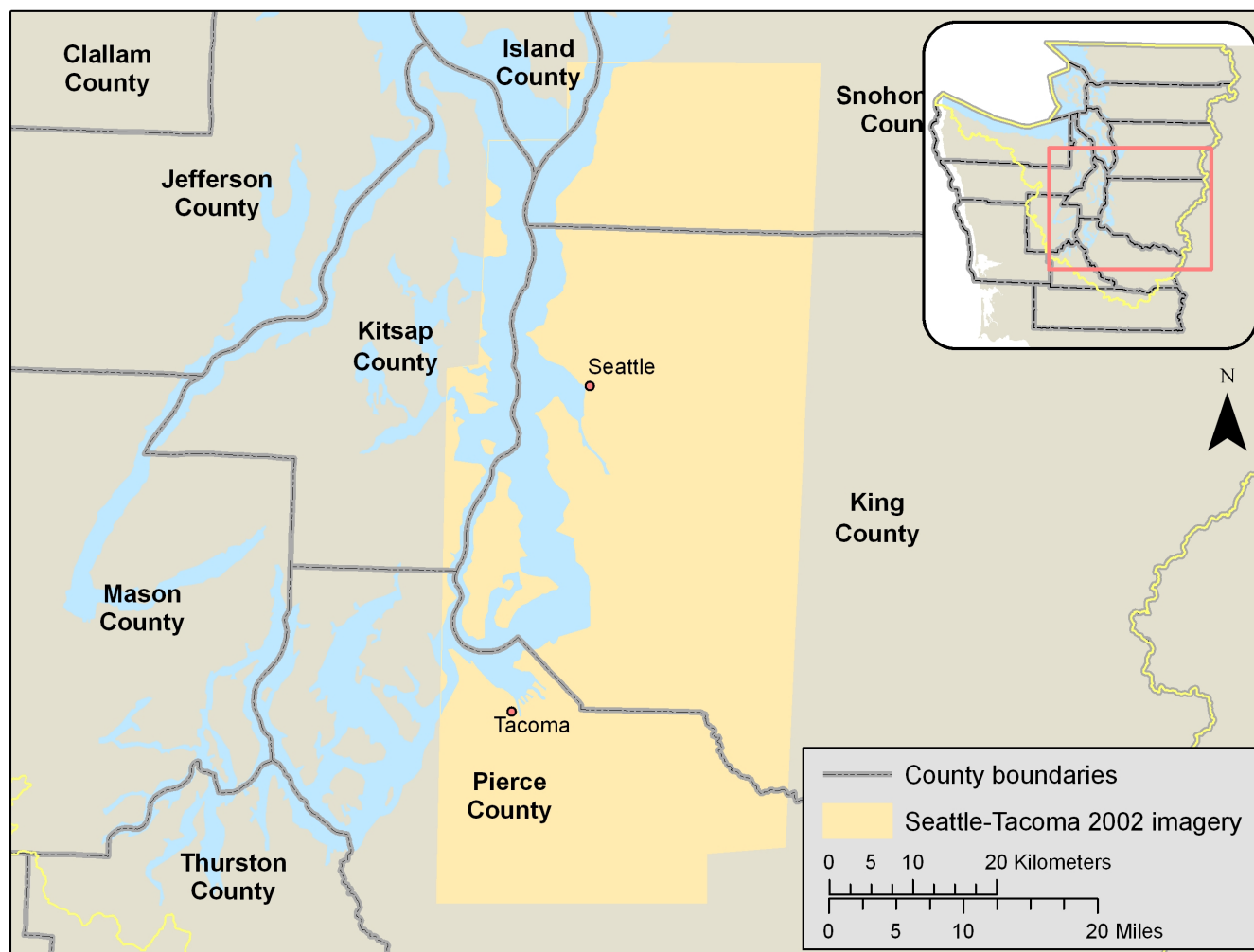


Figure 9. Map of the Seattle-Tacoma, Washington metropolitan area 2002 imagery coverage.

Snohomish County—2005 and 2007

The 2007 image dataset contains May-June 2007 digital ortho-imagery of Snohomish County. The Natural Color image pixel size is 1 foot, and coverage excludes USFS lands in the eastern portion of the county (fig. 10). Imagery was acquired by the Snohomish County Information Services Department.

The imagery is available in two formats: 1,133 tiled GeoTIFFs (114 GB) and four MrSID (9 GB) images that divide the county into 4 sections (NE, NW, SE and SW). Each of the GeoTIFF tiles cover a ground area of 6,000 feet by 6,000 feet and are in a state plane projection.

The 2005 (85 GB) image dataset has similar pixel and tile size as the 2007 dataset. Sufficient metadata is not available for the 2005 imagery.

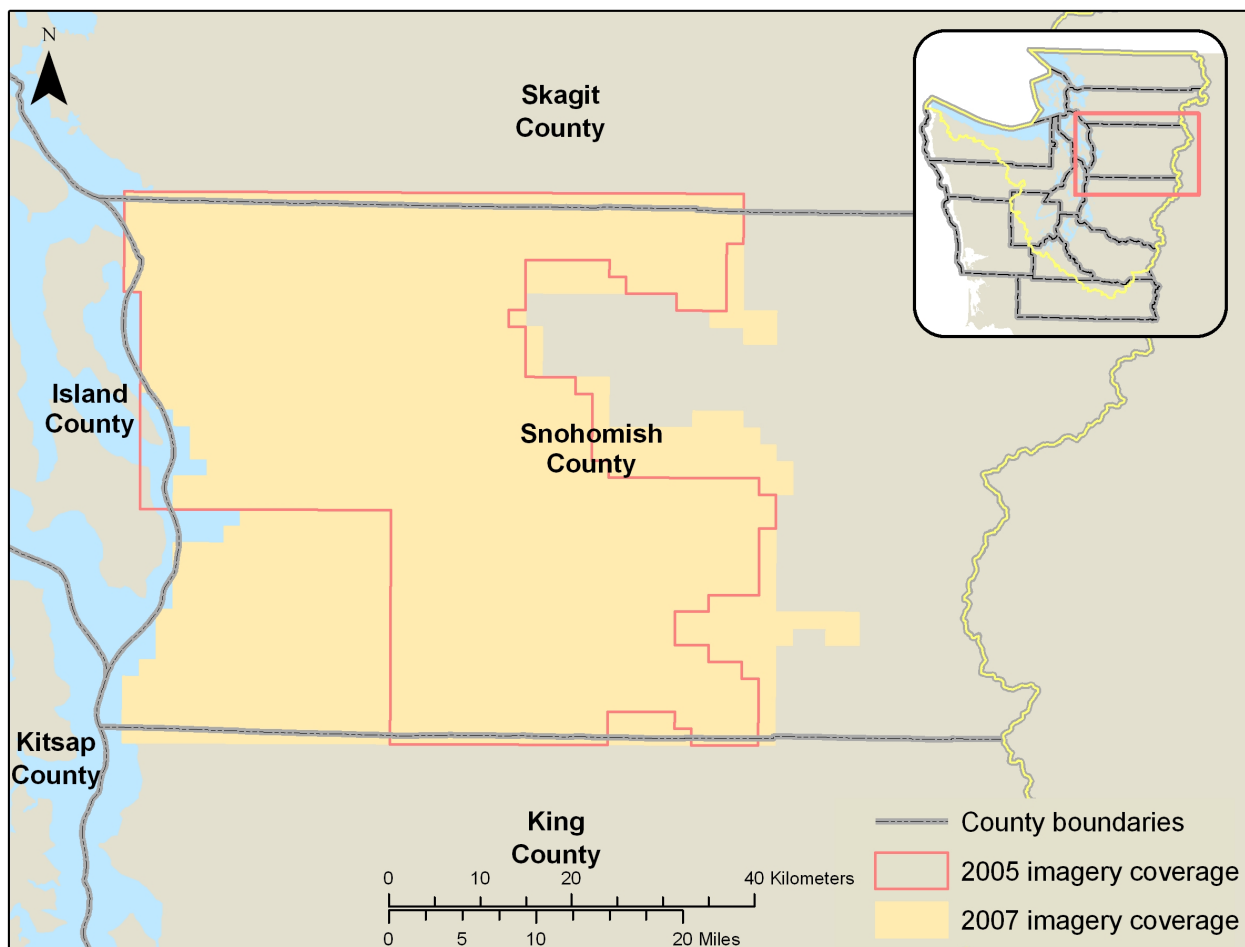


Figure 10. Map of Snohomish County, Washington 2005 and 2007 imagery coverage.

Elevation

Elevation or surface information is available for the study area in multiple formats and extents. In addition, these separate datasets often were derived by different techniques. Digital Elevation Models (10 meter) cover the entire Puget Sound Basin. Topobathy, a combination of both topography and bathymetry, is available for the Sound and Puget Lowlands. LiDAR (Light Detection and Ranging) data are available at partial discrete extents by various distributors.

USGS 10-meter Digital Elevation Model (DEM)

The National Elevation Dataset (NED) is a seamless digital-raster dataset developed by the USGS from several sources. The dataset totals 5 GB of data as single files for the Puget Sound Basin coverage and is in a UTM projection (fig. 11). Mosaic digital elevation models (2 GB) can be used to

create three-dimensional oblique views of the Puget Sound Basin by using the appropriate software (for example, ArcScene).

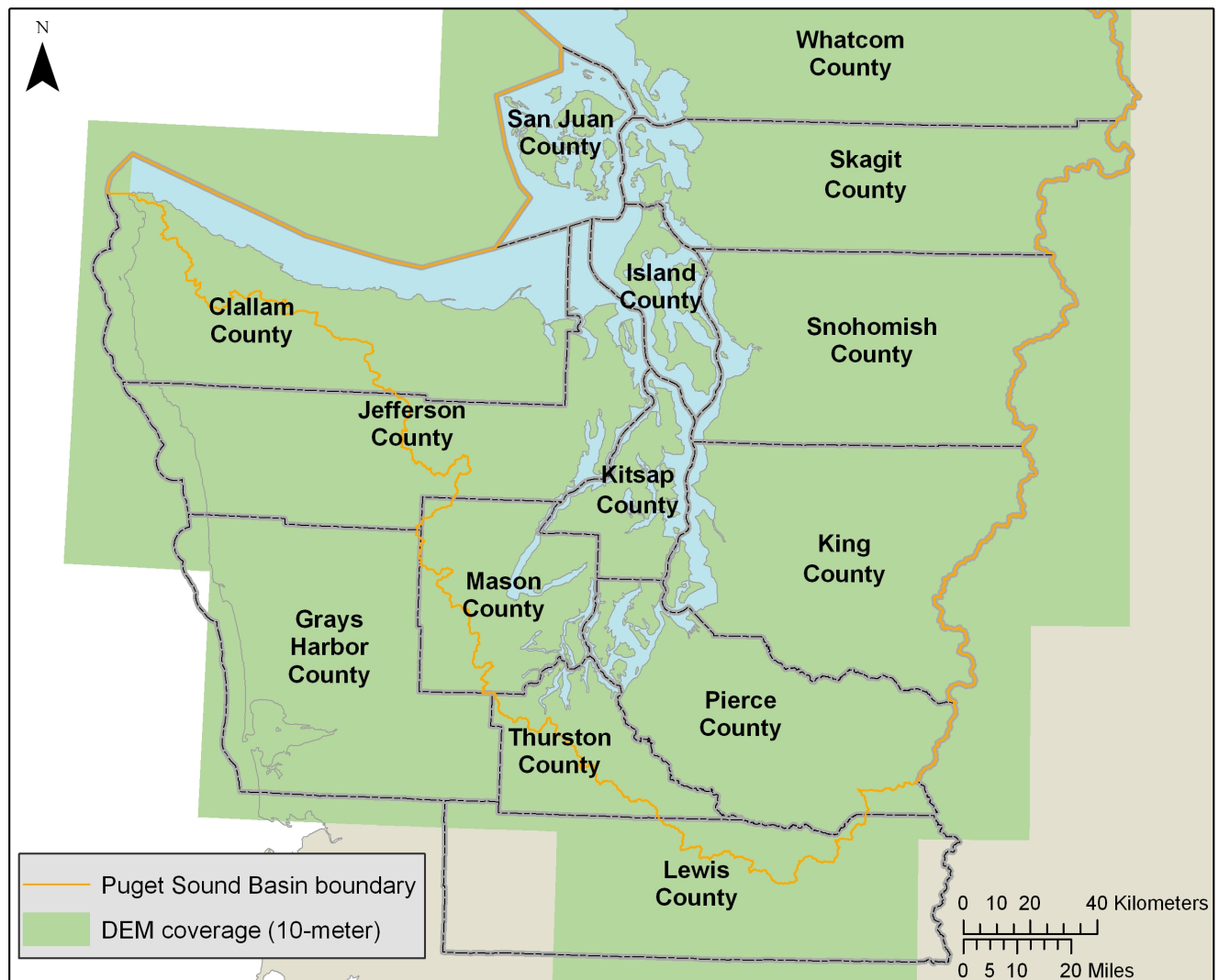


Figure 11. Map of the Puget Sound Basin U.S. Geological Survey National Elevation Dataset coverage.

Puget Sound Topobathy

These data combine topography and bathymetry into seamless datasets. There are two separate topobathy datasets at different extents: (1) Puget Lowland and (2) Western Washington (fig. 12).

The Puget Lowland dataset created in 2005 includes Puget Sound, Hood Canal, and Lake Washington. The dataset was derived from high resolution LiDAR and multibeam SONAR. The DEM has a 30-foot resolution in grid-raster format, is in a state-plane projection and is 580 MB.

The western Washington dataset is a 30-meter raster that covers most of western Washington, parts of Vancouver Island, and most of the inland territorial waters of the United States. The creators of the dataset note that high-quality Canadian bathymetry cannot be distributed freely and is, therefore, not included. The DEM is in a UTM projection and is 100 MB. Derived hillshade datasets (shaded-relief raster data) also are available for both extents of the topobathy.

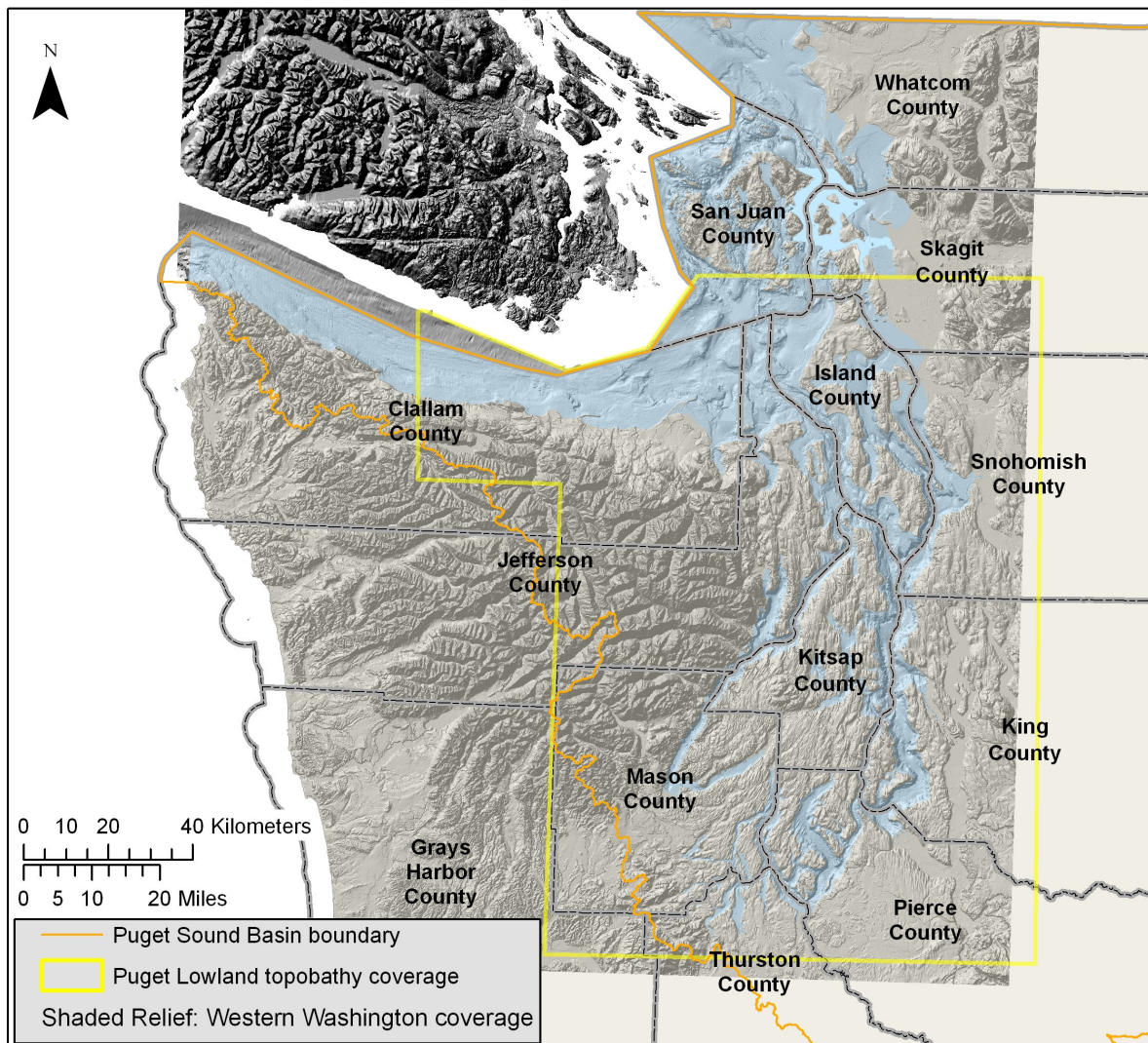


Figure 12. Map of the Puget Lowland (yellow boundary) and western Washington (shaded relief) topobathy coverage.

LiDAR

Light Detection and Radar (LiDAR) data for the Puget Sound Basin is gathered and processed by the Puget Sound LiDAR Consortium (PSLC). The PSLC was established in 1999 and includes participants from Kitsap County, Kitsap Public Utility District, City of Seattle, Puget Sound Regional

Council, NASA, USGS, Clallam County and Island County. The consortium funds LiDAR data acquisition for public-domain high-resolution LiDAR topography and derivative products for the Puget Sound Basin.

The coverage of these data includes most of the Puget Lowlands, all of Kitsap, Thurston, and King Counties, and most of Pierce County (fig. 13). These data are in both bare-earth and all-return ASCII formats. The captures of LiDAR data are acquired as separate projects, leaving no universal metadata for all datasets. Resolutions and dates of capture vary among projects. A complete metadata Web site by the PSLC for all projects can be found online at

<http://pugetsoundlidar.ess.washington.edu/lidardata/metadata.html>.

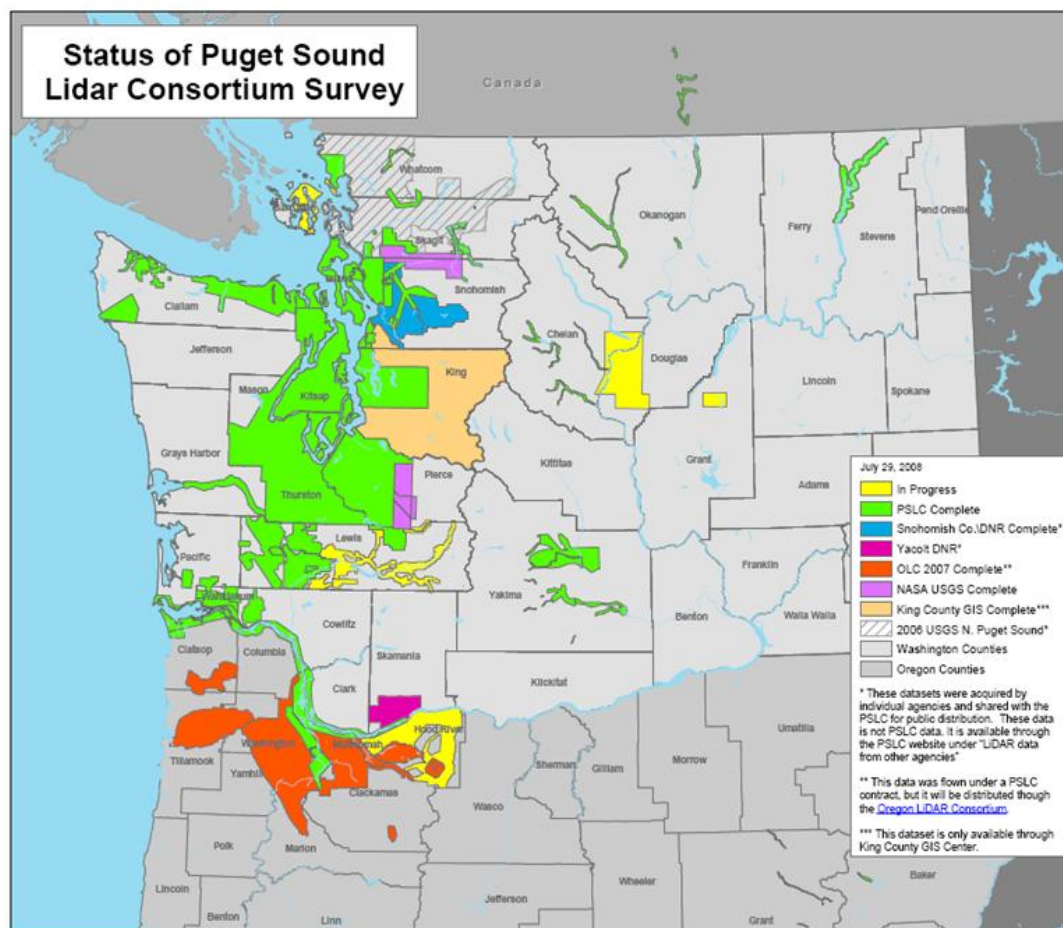


Figure 13. Map of the Expected Status of Puget Sound LiDAR Consortium Surveys as of July 2008. Puget Sound LiDAR Consortium, resolution of image dependent on screen capture,

http://pugetsoundlidar.ess.washington.edu/PSLC_status_map.pdf, last accessed September 25, 2008.

Jurisdictions and Boundaries

The PSILM pilot uses the entire Puget Sound Basin as a study area; within the basin there are multiple jurisdictions and lands managed by State, county, and Federal agencies.

County Boundaries

Washington State county boundaries were obtained from the Washington State Department of Ecology (Ecology), and the counties within the Puget Sound Basin were selected from the dataset. The 13 counties in the study area include Whatcom, Skagit, Snohomish, King, Pierce, Kitsap, Island, and San Juan; Thurston, Lewis, Mason, Jefferson, and Clallam counties are partially within the basin (fig. 14). The data are represented as vector polygons in Environmental Systems Research Institute (ESRI) shapefile format, a state-plane projection, and were published in 1999.



Figure 14. Map of the Puget Sound Basin county boundaries, Washington.

Cities and City Limits

Cities and urbanized areas in the Puget Sound Basin are represented in three datasets: (1) city and town points, (2) city-limit polygons, and (3) U.S. Census Bureau's Incorporated Places (fig. 15).

(1) The National Atlas dataset includes 387 cities and towns in the Puget Sound Basin. Those areas with a population of 50,000 or more are depicted in figure 15. These data were published in February 2004. Attributes of the city and town point data are in a state-plane projection and include the city name, population range, 2000 population, county, and FIPS (Federal Information Processing) codes.

(2) The city limit polygons dataset depict the boundaries of Washington's incorporated municipalities, as recorded by the Washington State Office of Financial Management. Each city's limits are represented by one or more polygons that are based on legal descriptions of the boundaries. Attributes include the city name and FIPS (Federal Information Processing Standards) code. The dataset is in a state-plane projection and was published in November 2007 by the Washington State Department of Transportation (WSDOT).

(3) The incorporated places dataset by the U.S. Census Bureau, defines places that were legally in existence on January 1, 2000, under the laws of their respective states, as cities, boroughs, towns, and villages. The incorporated places are represented by polygons in ESRI shapefile format and in a geographic coordinate system (GCS).

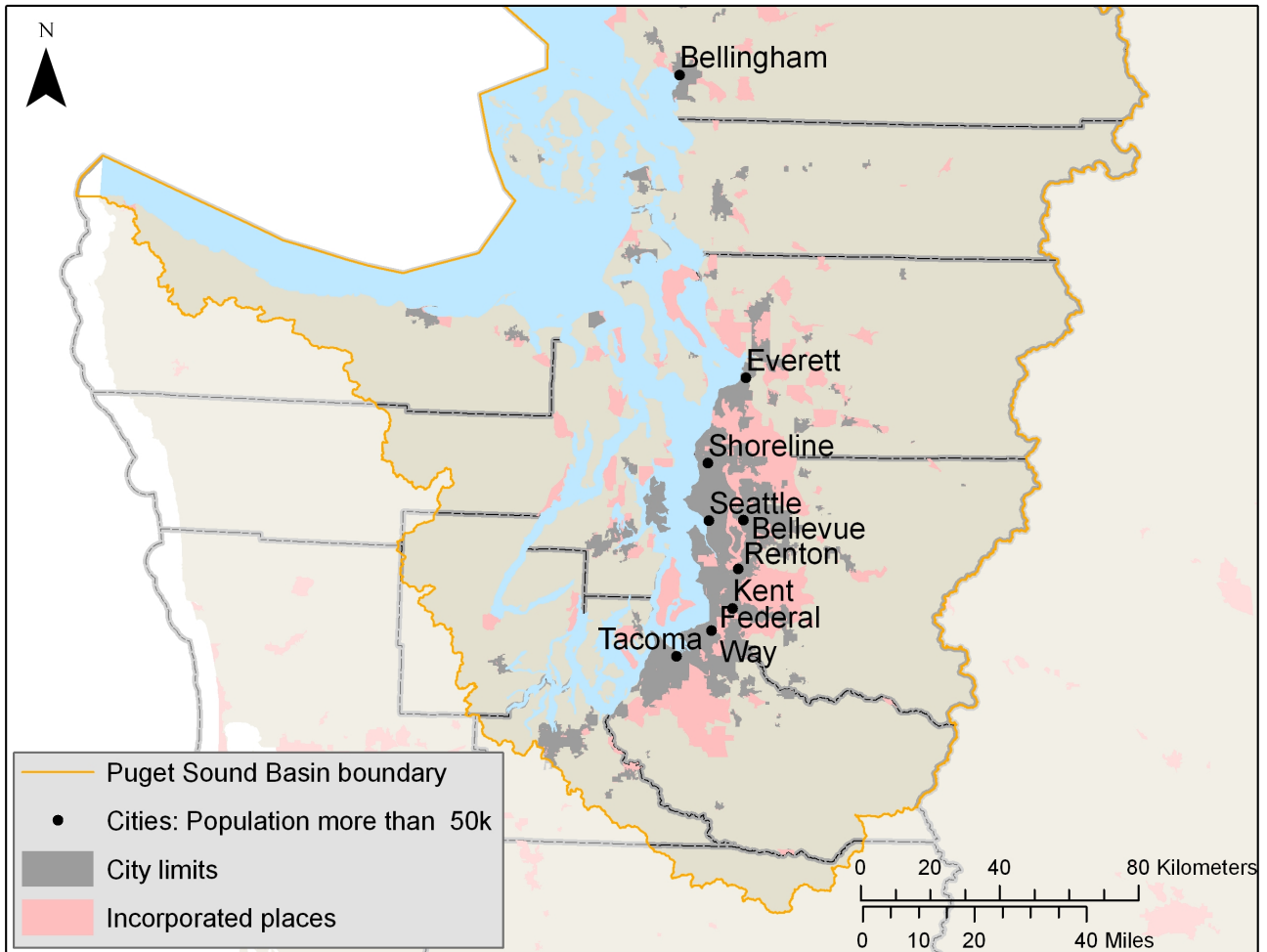


Figure 15. Map of urbanized areas, including city limits (gray), incorporated places (pink) and cities with populations greater than 50,000 in the Puget Sound Basin, Washington.

Puget Sound Partnership Action Areas

The Puget Sound Partnership is a Washington State agency formed by legislation passed in 2007. The Partnership is designed to work with communities, other government agencies, tribes, scientists, and businesses to restore and protect Puget Sound Basin. The Partnership is creating an Action Agenda that will prioritize restoration and protection efforts in the Sound, as well as coordinate interagency programs and resources.

The Puget Sound Basin was divided into seven Action Areas “based on common issues and interests, physical characteristics, and how water flows into and within the Sound” (fig. 16). The seven

Action Areas are defined as: San Juan Islands, Whidbey Island, South Central Puget Sound, South Puget Sound, North Central Puget Sound, Hood Canal, and Strait of Juan de Fuca.

The Action Area boundaries were created by the Partnership and digitized by the USGS for the PSILM pilot project. The Action Area dataset is in ESRI shapefile format in a state-plane projection, and attributes include Action Area names.

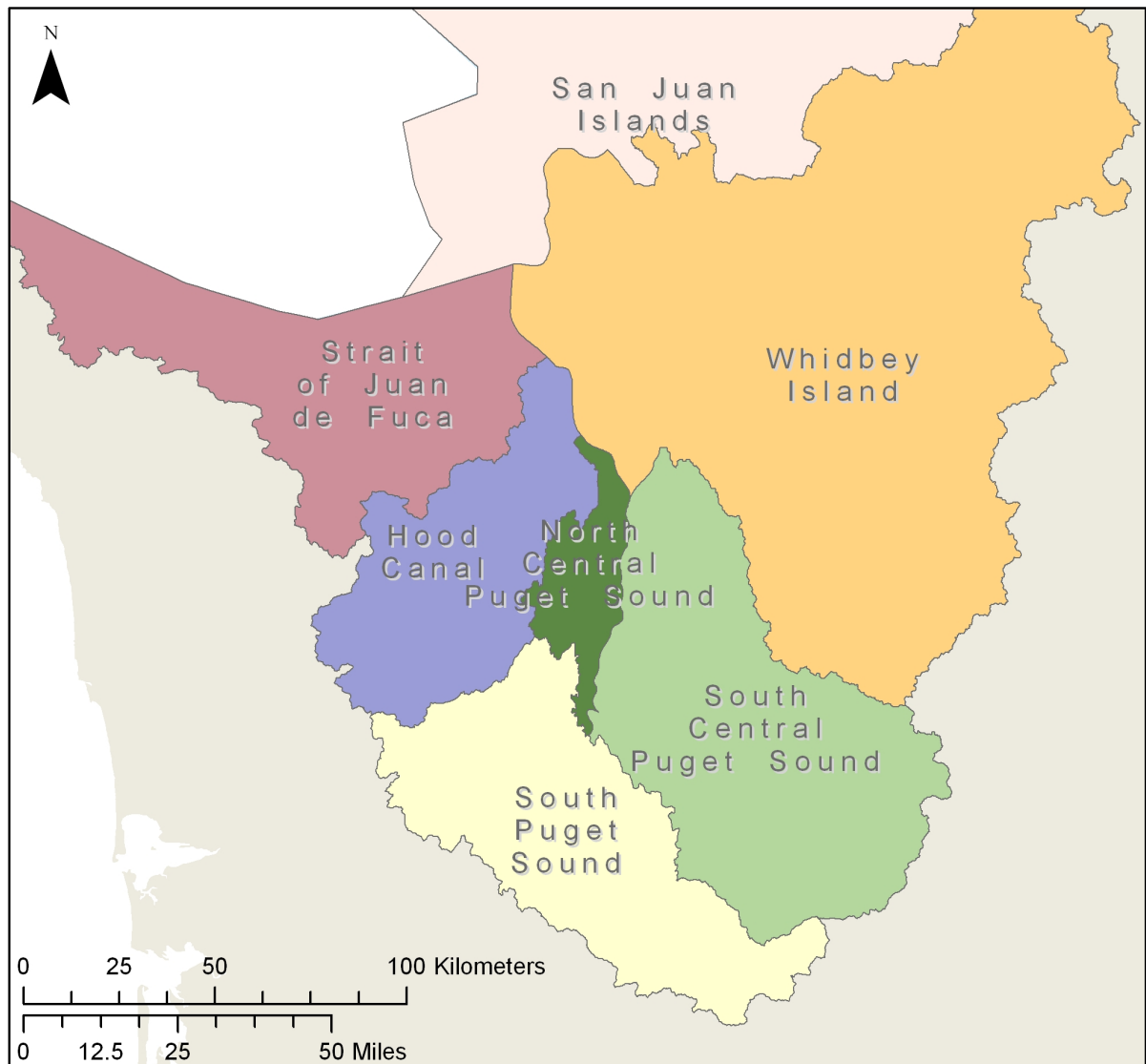


Figure 16. Map of the Puget Sound Partnership Action Area boundaries—San Juan Islands, Whidbey Island, South Central Puget Sound, South Puget Sound, North Central Puget Sound, Hood Canal, and Strait of Juan de Fuca, Washington.

National Parks and other Public Lands

Public lands are managed by several land managers in the Puget Sound Basin (fig. 17). The national parks dataset was created by the WSDOT and published in 1999. The dataset includes all national park land in Washington State of a “sufficient area” to be shown at a 1:24,000 scale. Data were digitized from USGS quads and other government resources. The data are in ESRI shapefile format and a state-plane projection.

The Washington State Non-Department of Natural Resources Major Public Lands (NDMPL) was created by the Washington State Department of Natural Resources (WA DNR) in 2005. Data contain ownership parcels for Federal, State (excluding WA DNR), county, and city lands within the State of Washington, as well as Tribal administrative boundaries.

WA DNR Managed Land Parcels, another dataset from WA DNR, includes all polygon boundaries of WA DNR managed parcels. Attributes include: parcel label and name, surface ownership, mineral-rights ownership, and timber-harvest rights. These two datasets are in a state plane projection and ESRI shapefile format.

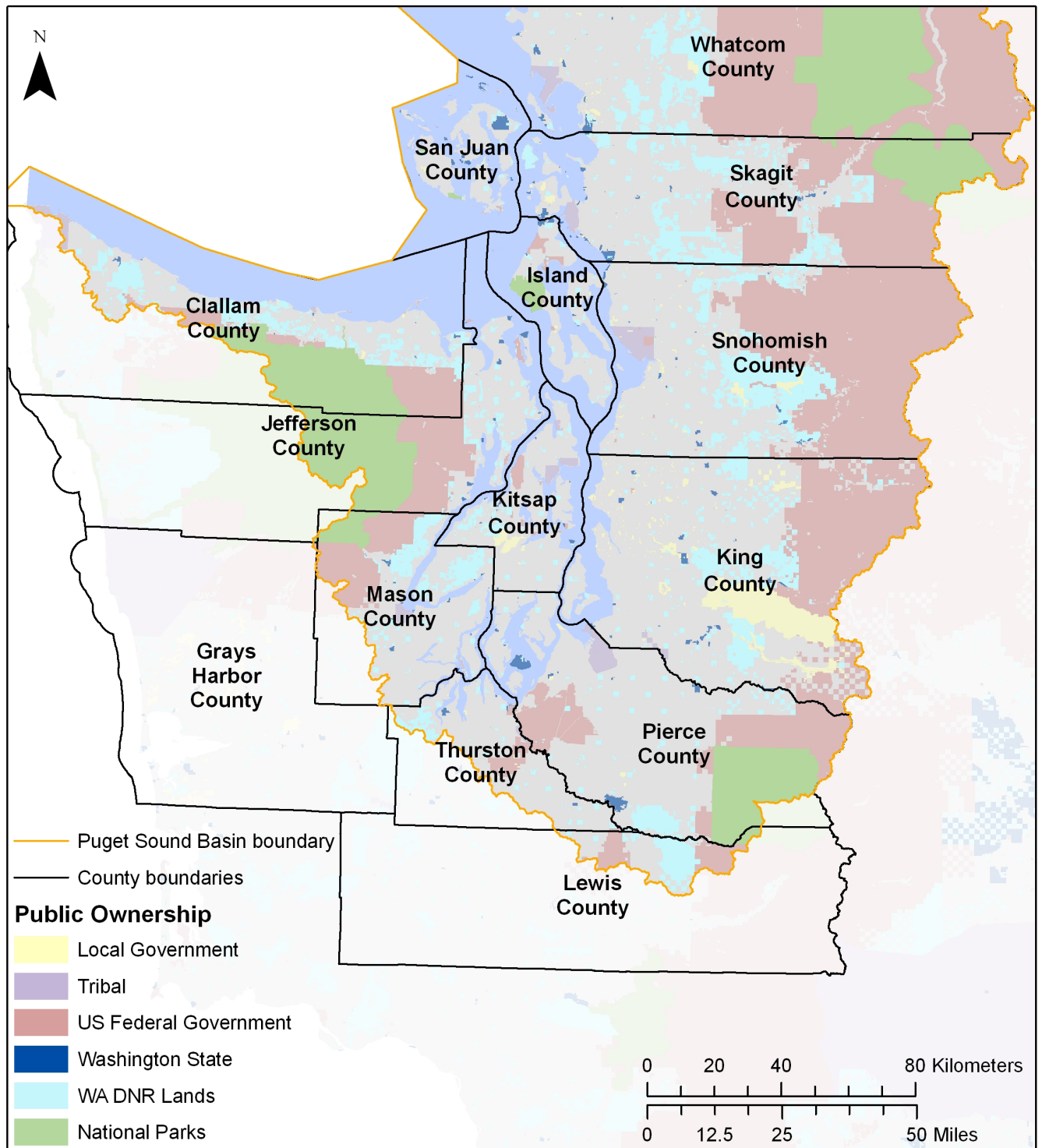


Figure 17. Map of publicly owned lands in the Puget Sound Basin, Washington.

Soil and Water Data

Digital soil-survey data is provided by the USDA Natural Resources Conservation Service (NRCS). Hydrography of the Puget Sound Basin charts the watercourses, waterbodies, and watershed basins of the area.

Natural Resources Conservation Service (NRCS) Soil Surveys

NRCS soil surveys are available from the soil-data mart in SSURGO format (<http://soildatamart.nrcs.usda.gov/>). Both spatial and tabular data are available, as well as metadata for each soil survey. The SSURGO format defines and groups specific soil-mapping units, series, and other soil attributes and describes the attribute relationships

<http://soildatamart.nrcs.usda.gov/SSURGOMetadata.aspx>).

Downloadable data for the Puget Sound Basin include 16 distinct soil surveys (table 2). No soil surveys were available for parts of Olympic, North Cascades, and Mount Rainier National Parks, or the northern part of the Mount Baker-Snoqualmie National Forest (fig. 18). Spatial coverage of the digital soil surveys is in decimal degrees.

Table 2. List of Digital Soil Surveys for the Puget Sound Basin, Washington.

County	Survey number	Survey name
Whatcom	WA673	Whatcom County Area
	WA749	Okanogan National Forest Area
Skagit	WA657	Skagit County Area
	WA749	Okanogan National Forest Area
Snohomish	WA661	Snohomish County Area
King	WA633	King County Area
	WA634	Snoqualmie Pass Area
Pierce	WA653	Pierce County Area
	WA634	Snoqualmie Pass Area
Kitsap	WA035	Kitsap County Area
Island	WA029	Island County
San Juan	WA055	San Juan County
Thurston	WA067	Thurston County
Lewis	WA641	Lewis County Area
Mason	WA645	Mason County
	WA632	Olympic National Forest Area
Jefferson	WA631	Jefferson County Area
	WA632	Olympic National Forest Area
Clallam	WA609	Clallam County Area
	WA632	Olympic National Forest Area

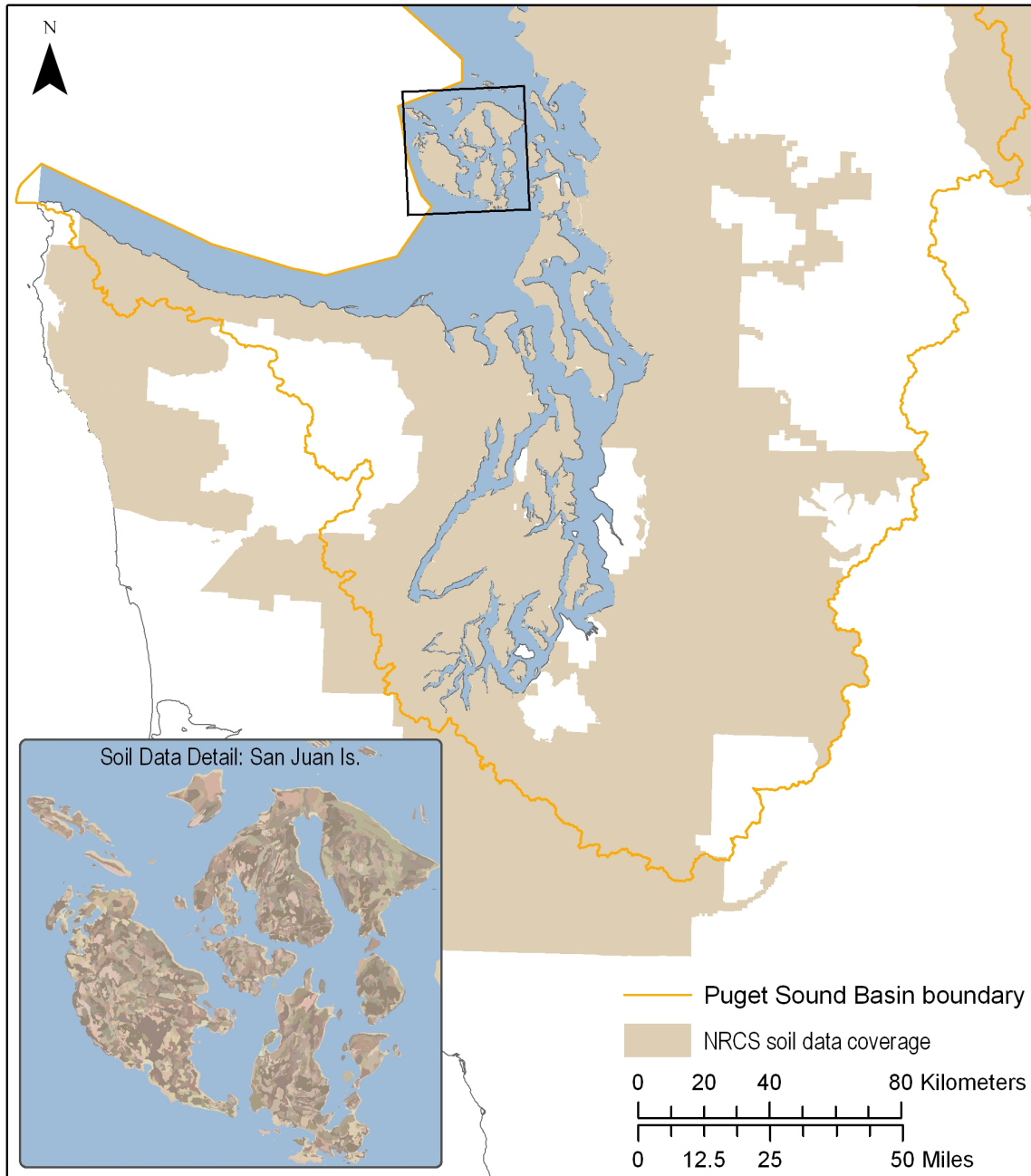


Figure 18. Natural Resources Conservation Service (NRCS) soil-data coverage in the Puget Sound Basin, Washington.

Washington Water Resource Inventory Areas (WRIA)

WRIAs were authorized under the Water Resources Act of 1971 and Washington State agencies use the WRIA system to refer to the State’s major watershed basins. Watershed planning and other

watershed related programs (for example, Water Cleanup Plans) use WRIs to describe watersheds within the state. There are 19 WRIs that make up the Puget Sound Basin (fig. 19).

The dataset is in ESRI shapefile format and a state plane projection. Attributes include the WRI name, identification, area, and number. The publication date for the data is May 2000.

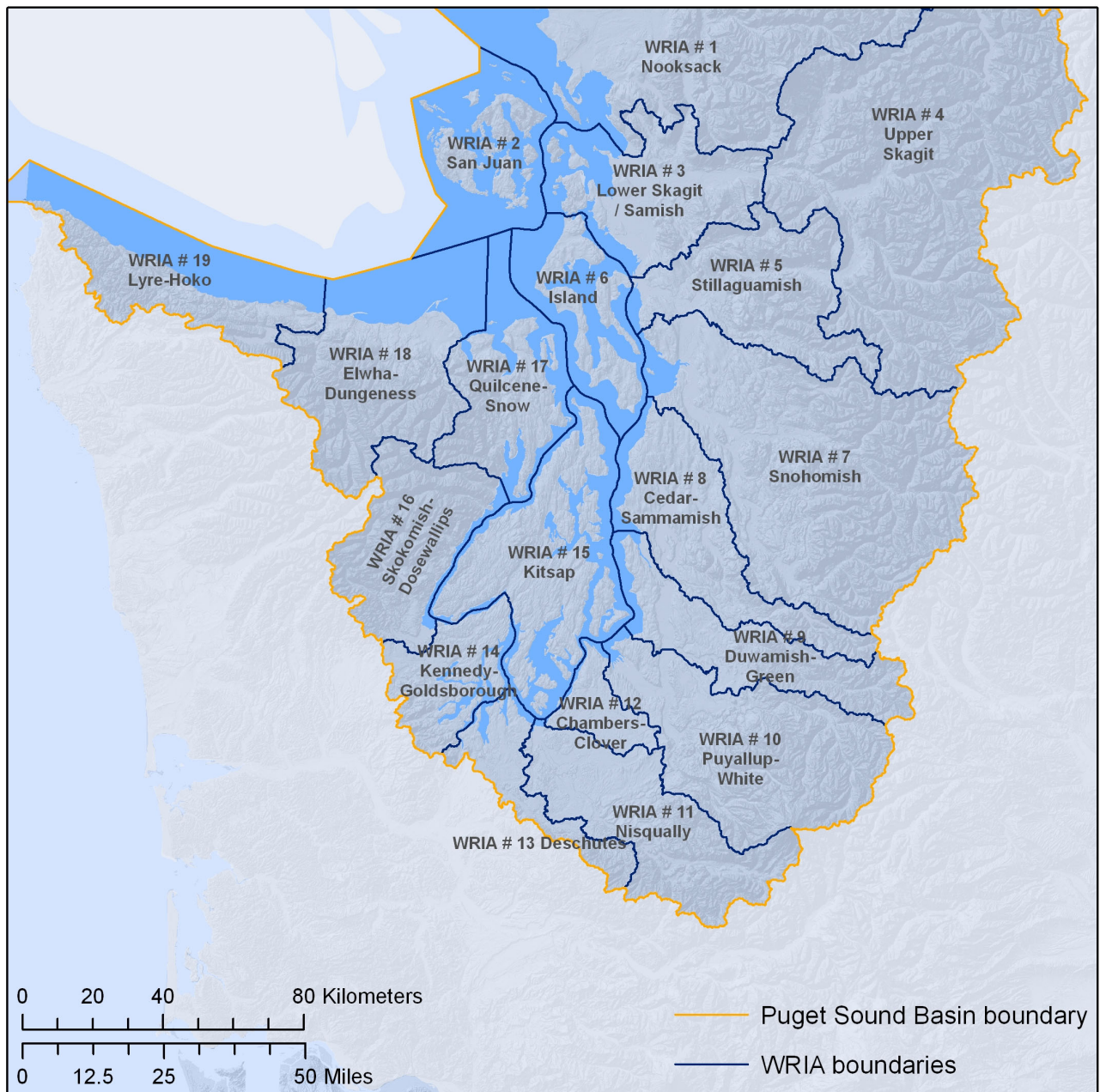


Figure 19. Map of the Water Resource Inventory Areas (WRIA), Washington; there are 19 WRIs in the Puget Sound Basin, Washington.

Waterbodies and Watercourses

Waterbodies and watercourses data were compiled by WA DNR. The hydrography data were published March 2006 and include two data files; together, the waterbodies and water courses make up the most comprehensive hydrography layer for Washington (fig. 20) at a 1:24,000 scale.

Watercourses are represented by arcs or lines. The dataset is 120 MB in ESRI shapefile format and in a state-plane projection. There are more than 30 attributes, including: watercourse cartographic-feature code (WC_CART_FT); watercourse-line type (WC_LN_TYPE); watercourse hydrographic-feature code, such as lakes, glaciers, bays (WC_HYDR_FT); and several attributes that pertain to the Forest Practices Fish Habitat Water Type System. The dataset's metadata has a complete listing and description of all attributes.

Waterbodies are represented by polygons. The dataset is 25 MB in ESRI shapefile format. Attributes include a water body cartographic-feature code (WB_CART_FT) that describes which feature type the water-body polygon represents (for example, glacier, bay, canal); and Water Body GNIS (Geographic Names Information System; WB_GNIS_NM) as contained within the USGS GNIS database: <http://geonames.usgs.gov/domestic/index.html>. Not all features will have a GNIS entry. Other attributes include WA DNR Forest Practices Fish-Habitat Water-Type Code (FP_WTRTY_C) and the Water body hydrographic-feature code (WB_HYDR_FT).

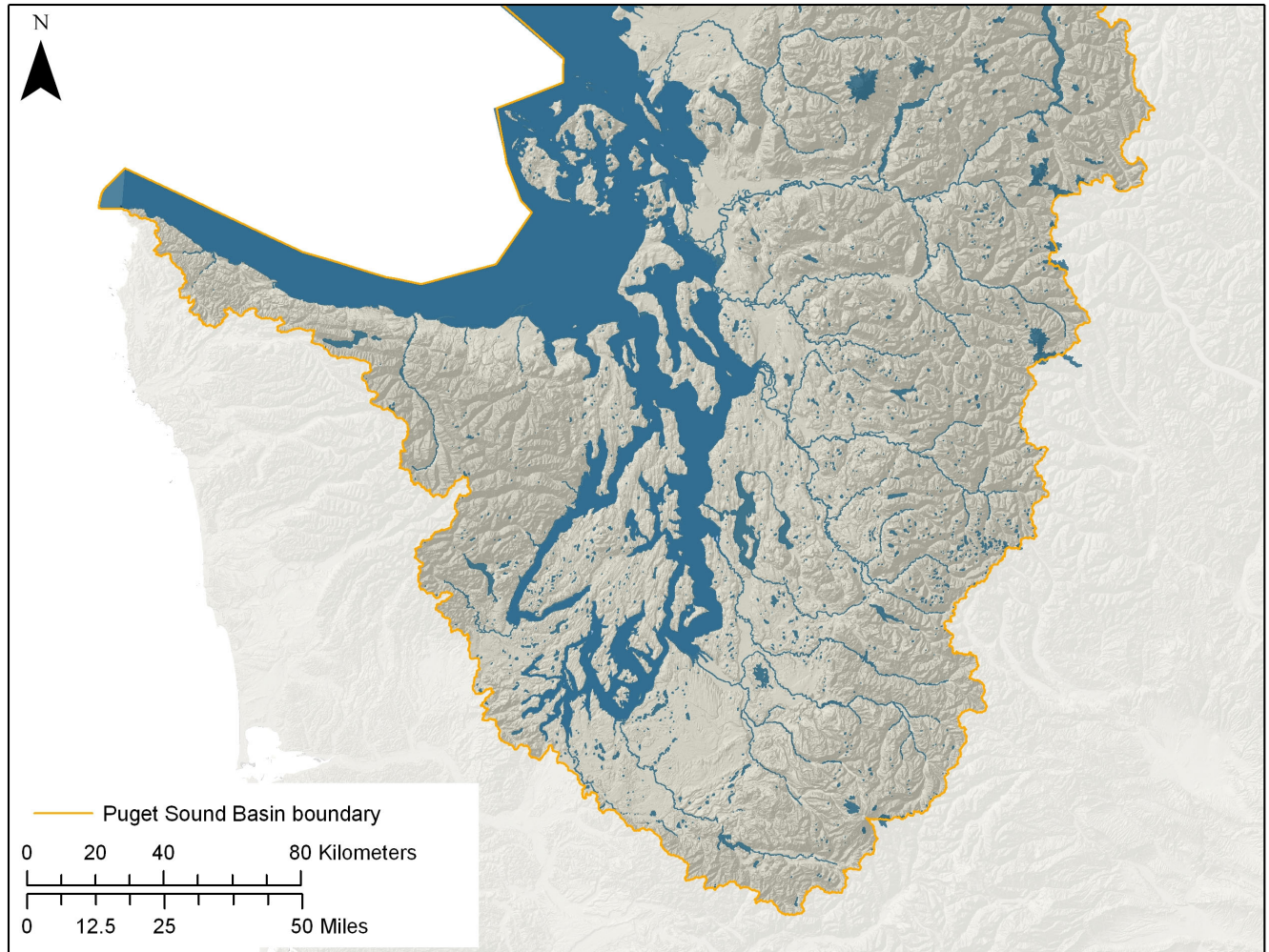


Figure 20. Map of waterbodies and watercourses in the Puget Sound Basin, Washington.

National Hydrographic Dataset

The National Hydrography Dataset (NHD), published by the USGS, is a set of digital spatial data of surface-water features, such as lakes, ponds, streams, rivers, springs, and wells (<http://nhd.usgs.gov/>). The NHD includes boundaries of hydrologic unit code (HUC) maps that have a nested structure consisting of basin, region, subbasin, subregion, subwatershed, and watershed. NHD data are available by subbasin or HUC-8 (fig. 21). There are 22 subbasins within the Puget Sound Basin (table 3). The NHD is available in ESRI geodatabase, coverage, and shapefile formats in a geographic coordinate system (GCS).

Table 3. List of Hydrologic Unit Codes (HUC) and Names for the Puget Sound Basin, Washington.

HUC code	HUC name
17100101	Hoh-Quillayute
17110001	Fraser
17110002	Strait of Georgia
17110003	San Juan Islands
17110004	Nooksack
17110005	Upper Skagit
17110006	Sauk
17110007	Lower Skagit
17110008	Stillaguamish
17110009	Skykomish
17110010	Snoqualmie
17110011	Snohomish
17110012	Lake Washington
17110013	Duwamish
17110014	Puyallup
17110015	Nisqually
17110016	Deschutes
17110017	Skokomish
17110018	Hood Canal
17110019	Puget Sound
17110020	Dungeness-Elwha
17110021	Crescent-Hoko

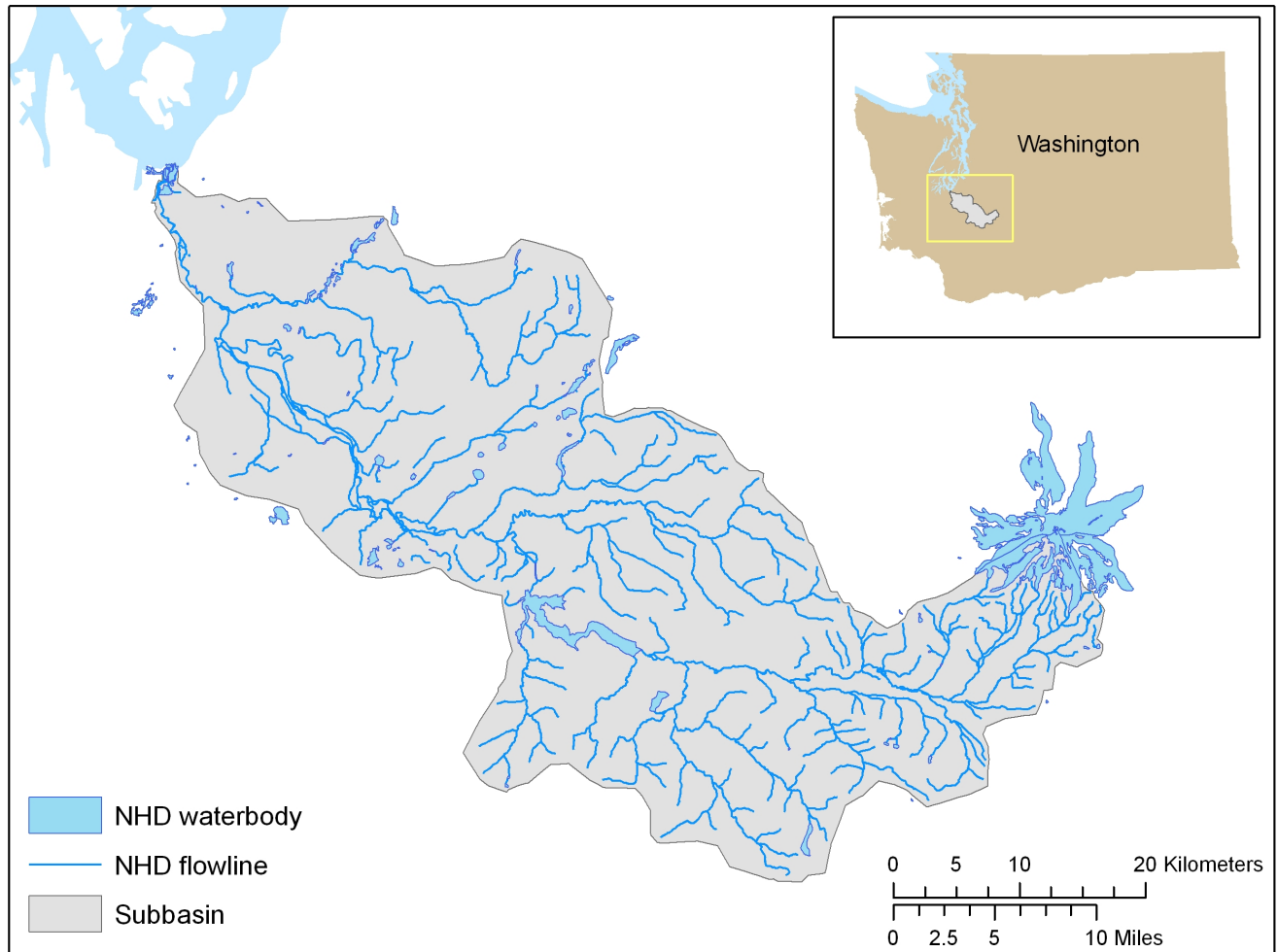


Figure 21. Map of National Hydrographic Dataset data for HUC 17110015, Nisqually Subbasin, Puget Sound Basin, Washington.

Marine and Coastal Data

Marine and coastal data includes shoreline slope stability from Ecology and Marine Protected Areas (MPA) from the Washington Department of Fish and Wildlife (WDFW). Marine water quality, kelp-monitoring information, and a Shore Zone inventory by the WA DNR can be found in the Monitoring section of this document.

Shoreline Slope Stability

The shoreline slope stability dataset was produced by Ecology's Shorelands and Coastal Zone Management Program. It is a digitization of the Coastal Zone Atlas of Washington that was originally published between 1978 and 1980.

These data indicate the relative stability of coastal slopes, as interpreted by geologists, based on aerial photographs, geological mapping, topography, and field observations (fig. 22).

Mapping of slope stability in the Coastal Zone Atlas extends only 2,000 feet inland from the shoreline. Mapping was carried out only in those areas under direct State shoreline jurisdiction and, therefore, did not include Federal military installations or Indian Reservations.

The dataset is in polygon ESRI shapefile format in a state-plane projection. Attributes include Slope Stability Type (SLP_CLASS), Location Name, and area in Acres and Hectares.

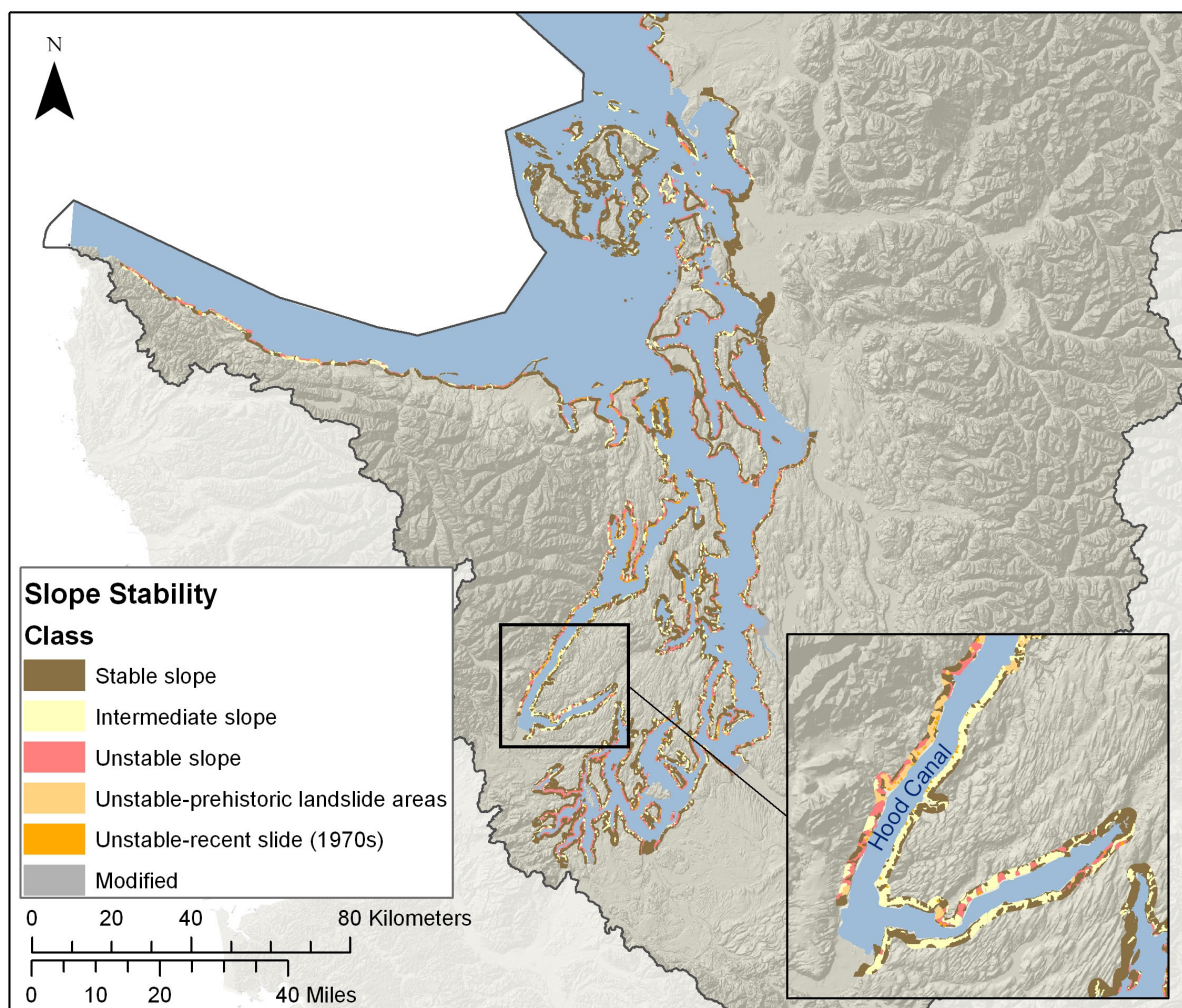


Figure 22. Map of slope stability of Puget Sound shoreline, Washington, with Hood Canal inset.

Washington Department of Fish Wildlife Marine Protected Areas (MPA)

The WDFW administer Marine Protected Areas (MPA) in Puget Sound for the protection and preservation of species and/or habitat (fig. 23).

The datasets that illustrate the locations of WDFW MPAs are in ESRI coverage format in a state-plane projection. The coverages include a main layer that shows all MPAs described under the Washington Administrative Code, Marine Fish-Shellfish Management and Catch Reporting Areas, Puget Sound, Title 220, Chapter 22, Section 400 (*WAC 220-22-400*; <http://apps.leg.wa.gov/WAC/default.aspx?cite=220-22-400>). A second coverage illustrates the areas with restrictions on the taking of sea cucumbers not shown in figure 23.



Figure 23. Map of Washington Department of Fish and Wildlife (WDFW) Marine Protected Areas (MPAs), Puget Sound Basin, Washington.

Climate

Climate data was acquired from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) Group at Oregon State University (OSU). The PRISM model is used to create spatial climate datasets for the contiguous United States.

Precipitation Normals

This dataset contains spatially gridded average monthly and annual precipitation for 1971-2000 for the contiguous United States. Distribution of the point measurements to a spatial grid was accomplished by using the PRISM model, developed and applied by Chris Daly of the OSU PRISM Group.

Datasets are in ESRI grid format and a GCS. There is one dataset for each month's average precipitation (ppt_7100_01 to 12) and an annual precipitation dataset (ppt_7100_14). The data have a spatial resolution of 30-arcseconds (800 meters) and the unit of measure is millimeters times 100.

Maximum Temperature Normals

This dataset contains spatially gridded average monthly and annual maximum temperatures for 1971-2000 in the contiguous United States. Distribution of the point measurements to a spatial grid was accomplished by using the PRISM model.

Datasets are in ESRI grid format and a GCS. There is one dataset for each month's average maximum temperature (tmax_7100_01 to 12) and an annual maximum temperature dataset (tmax_7100_14). The data have a spatial resolution of 30-arcseconds (800 meters), and the unit of measure is degrees Celsius times 100.

Minimum Temperature Normals

This dataset contains spatially gridded average monthly and annual minimum temperature for 1971-2000 in the contiguous United States. Distribution of the point measurements to a spatial grid was accomplished by using the PRISM model.

Datasets are in ESRI grid format and a GCS. There is one dataset for each month's average minimum temperature (tmin_7100_01 to 12) and an annual minimum temperature dataset (tmin_7100_14). The data have a spatial resolution of 30-arcseconds (800 meters), and the unit of measure is degrees Celsius times 100.

Transportation

The transportation data collected for PSILM consists of a statewide roads layer by the WA DNR.

Washington State Department of Natural Resources Transportation Data Layer

The Transportation data layer was published by the WA DNR in February 1996. The data layer includes linear data representing paved primary highways, secondary highways, light-duty and unimproved roads, trails, and other land- and water-transportation routes (fig. 24). The source data was at a scale of 1:24,000, and the digital dataset for the Puget Sound Basin is approximately 127 MB in size and in a state-plane projection.

No accuracy assessment has been performed on the dataset, and caution should be exercised when assessing the results of GIS analysis involving these data.

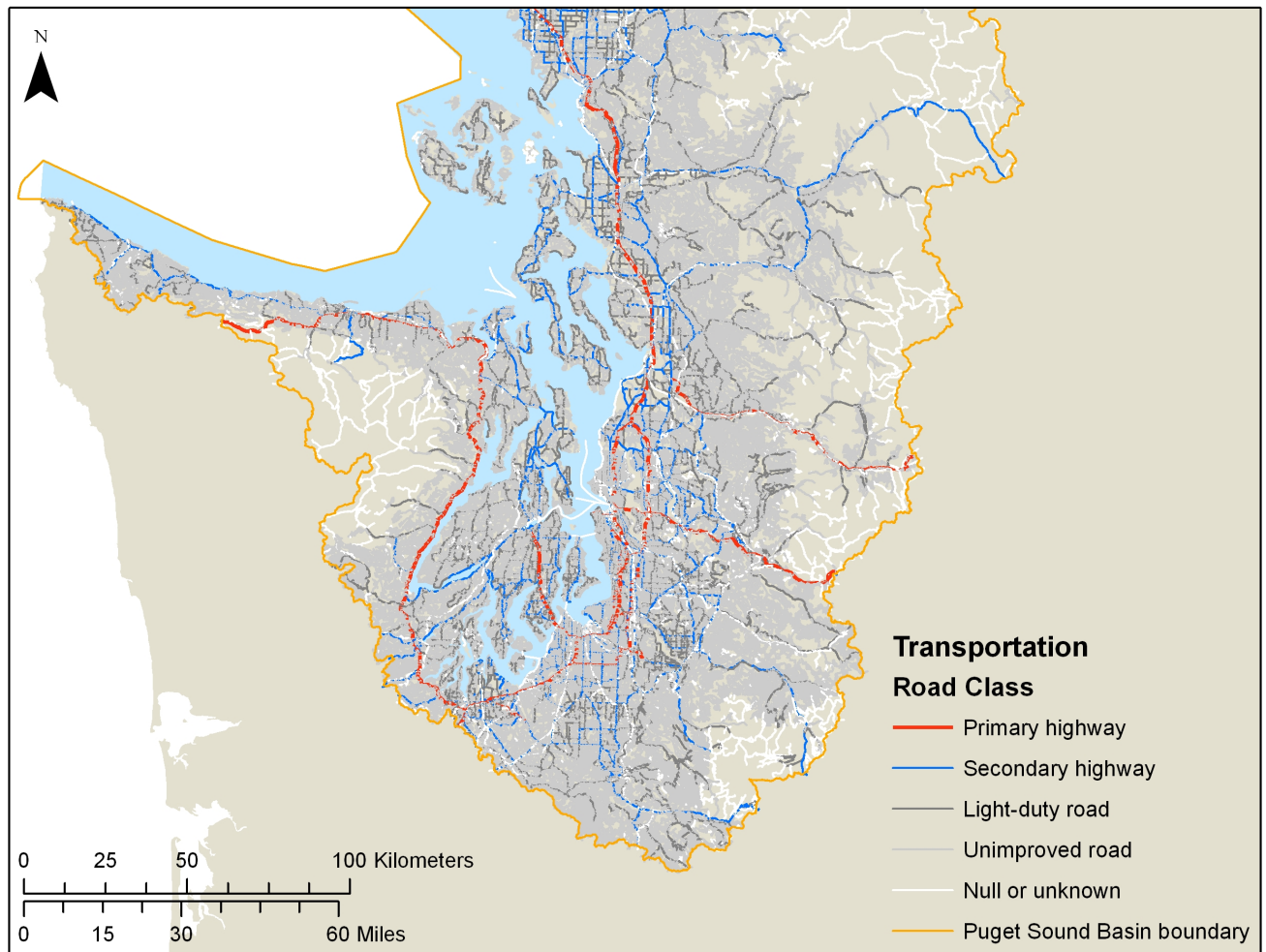


Figure 24. Map of the Washington State Department of Natural Resources (WA DNR) Transportation Road Classes in Puget Sound Basin, Washington showing primary highways (red), secondary highways (blue), and light-duty and unimproved roads (gray).

Land Cover

Four land-cover datasets were collected and catalogued for PSILM activities. They are all derived from the same suite of Landsat satellite sources and differ mainly in the year of acquisition, interpretation method, and repeat cycle for change-detection derivatives.

National Land Cover Dataset (NLCD)—2000 Washington State

The National Land Cover Dataset (NLCD) was compiled from Landsat satellite thematic mapper (TM) data with a spatial resolution of 30 meters. The NLCD has 21 classes in 9 categories: water,

barren, shrubland, vegetation, wetlands, developed, forested upland, non-natural woody, and herbaceous planted/cultivated (fig. 25).

The NLCD was produced as a cooperative effort between the USGS and the U.S. Environmental Protection Agency (USEPA) to produce a consistent land-cover data layer for the conterminous United States by using early 1990s Landsat TM data. The NLCD image is in TIFF format and in the Albers Equal Area Conic projection (USG version). There is also a 1992 version of the NLCD dataset. This version used a different automated interpretation, but is similar in land-cover classification categories and the use of Landsat data.

The analysis and interpretation of the satellite imagery for the 2000 dataset was done by using very large, sometimes multistate image mosaics (for example, up to 18 Landsat scenes). By using a relatively small number of aerial photographs for “ground truth”, the thematic interpretations were necessarily conducted from a spatially-broad perspective. Furthermore, the accuracy assessments correspond to “Federal regions” which are groupings of contiguous states. Thus, the reliability of the data is greatest at the state or multistate level.

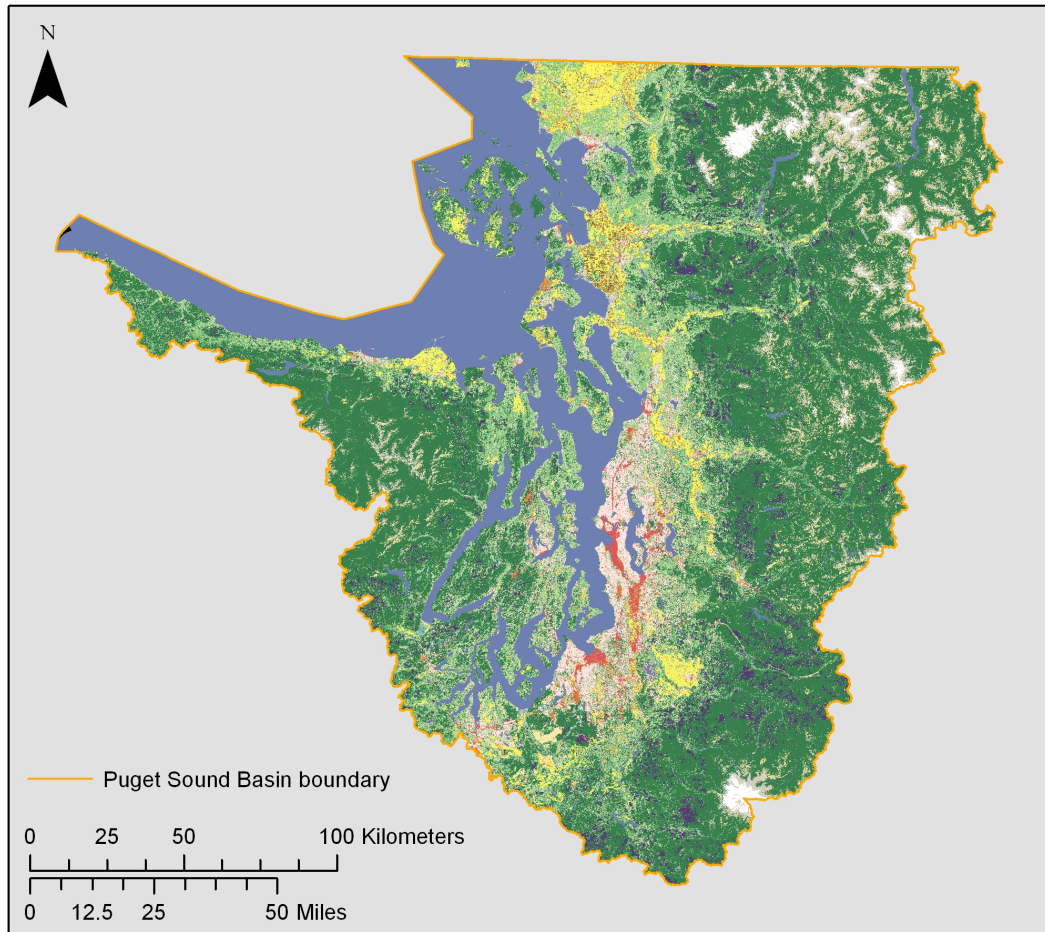


Figure 25. 2000 National Land Cover Dataset (NLCD) for the Puget Sound Basin boundary, Washington.

Land Cover Trends, Puget Lowlands, Washington, U.S. Geological Survey

The Land Cover Trends project estimates the rate of land-use and land-cover change at the USEPA designated Level III ecoregion extents. This Land Cover Trends project performed land-cover mapping and change-detection analysis at four time intervals (1973-79, 1979-86, 1986-92, and 1992-2000) for 32 randomly selected sample blocks (10x10-kilometer) within the Puget Lowland ecoregion (fig. 26; Sorenson, 2008).

The classification system used for the Land Cover Trends project is modified from the Anderson land use/land-cover system and has eleven classes: water, developed, mechanically disturbed, mining, barren, forest, grassland/shrubland, agriculture, wetland, nonmechanically disturbed, and ice and snow. All but the ice and snow class were mapped in the Puget Lowland ecoregion, which does not include higher elevations like those found in the Cascades.

The Puget Lowland land-cover class that illustrated the most change was forest lands, a major driving force behind the change being forest logging (Sorenson, 2008). Results and data products from this project include the mapped land-cover blocks, change-detection analysis, Landsat satellite imagery used for the land-cover mapping analysis, and summary-report documents. Data are in IMAGINE format and in the Albers Equal Area Conic projection (USGS version). More information on the Land Cover Trends Project can be found online (<http://landcoverrends.usgs.gov/index.html>).

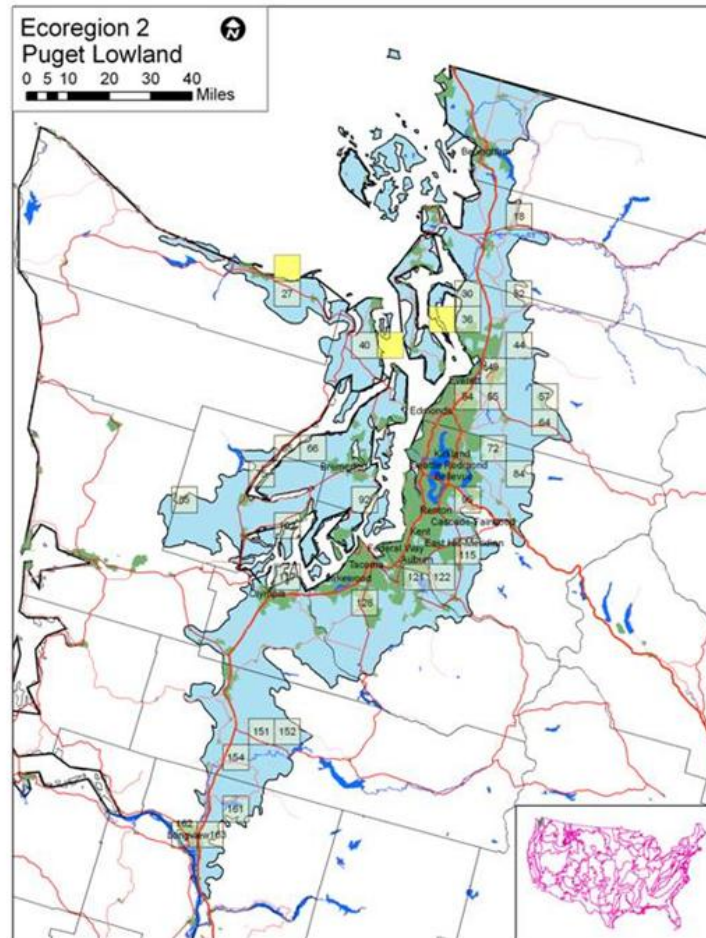


Figure 26. Map of Washington's Puget Lowland ecoregion, showing Land Cover Trends project sample blocks used to determine land-use and land-cover change (Sorenson, 2008).

National Oceanic and Atmospheric Administration Pacific Coast Land Cover

The National Oceanic and Atmospheric Administration (NOAA) produced a 1995 and 2000 land-cover classification and change-detection analysis of the Pacific Coast (fig. 27). The Puget Sound Basin, PSILM pilot study area, is included in NOAA's analysis. NOAA used 30-meter resolution

Landsat Thematic Mapper and Landsat Enhanced Thematic Mapper satellite imagery for the land-cover data. Twenty land-cover classes were generated from the remotely sensed data; overall accuracy for Washington and Oregon classifications combined is 86.1 percent. The imagery is in IMAGINE format and the Albers Equal Area Conic projection (USGS version).

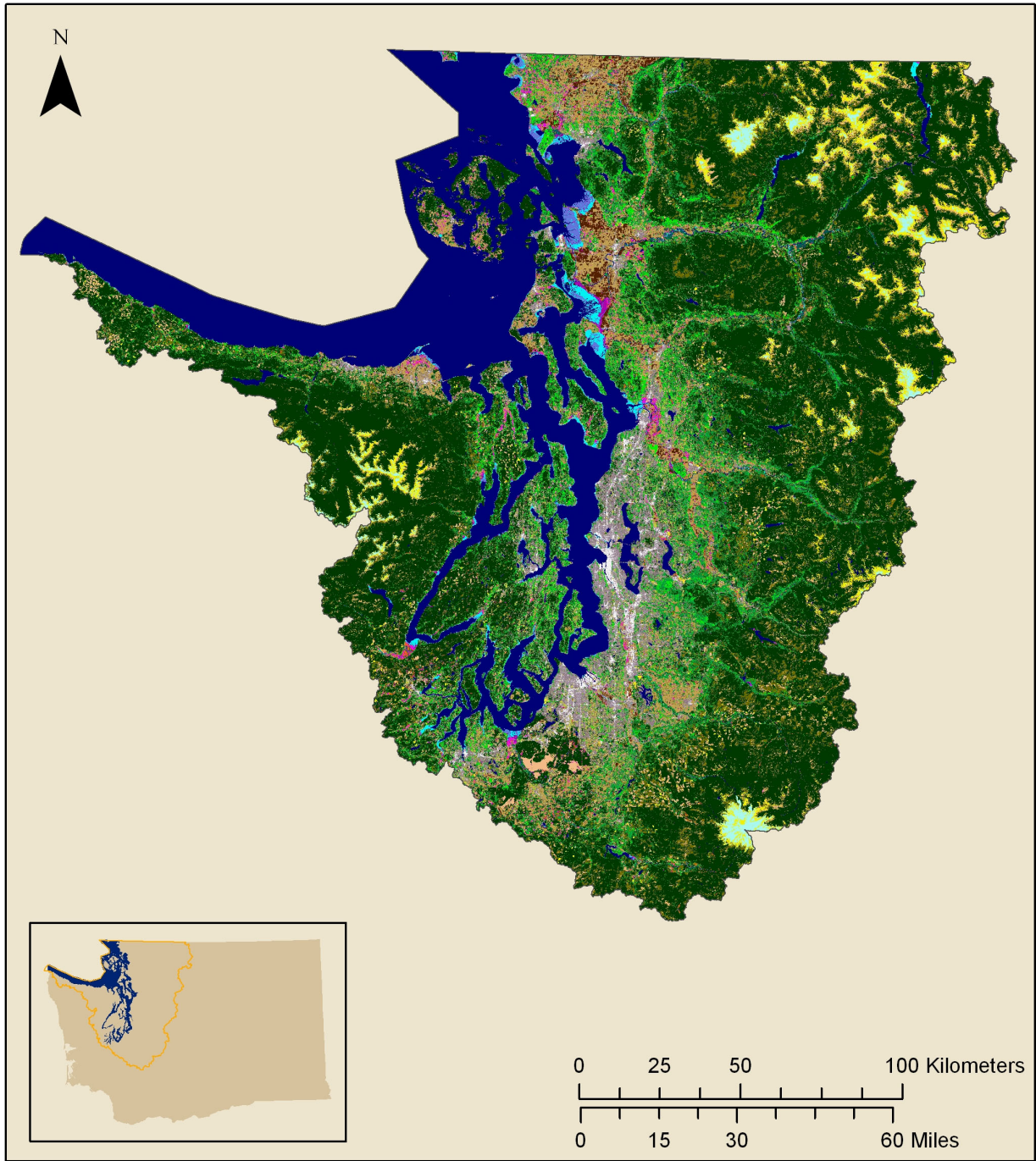


Figure 27. Map of the National Oceanic and Atmospheric Administration (NOAA) 2000 Land Cover for the Puget Sound Basin, Washington.

Gap Analysis Program (GAP) Washington State

The Gap Analysis Program is a nation-wide initiative to use mapped areas of biological and ecological importance in order to inform management of areas that are a high conservation priority. The GAP is administered by the USGS Biological Resources Discipline. The program uses land-cover, vegetation, and specific terrestrial-vertebrate distributions in order to produce GAP data products. The product results include land cover and vegetation maps, vertebrate-distribution models, and ecozones for Washington State. The land cover is derived from 1991 Landsat data (fig. 28). The GAP data products are in vector format with a minimum mapping unit of 100 hectares.

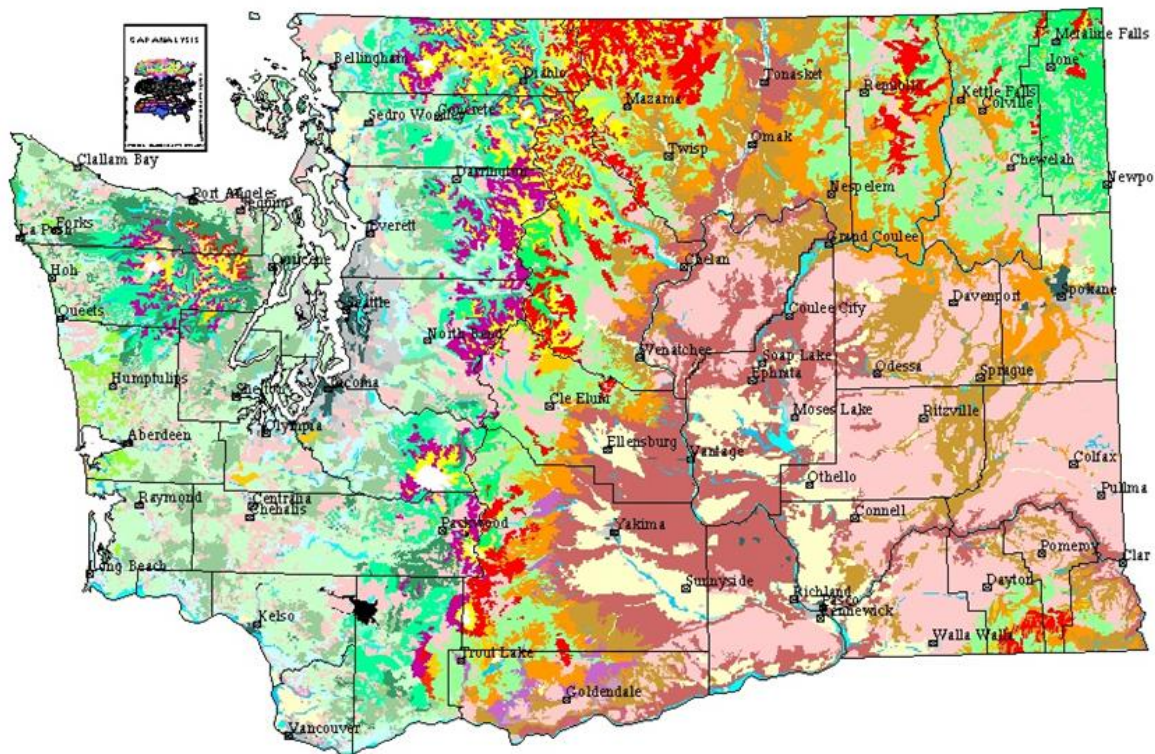


Figure 28. Washington State Gap Analysis Program Land Cover, Version 6, 1996 (WDFW, 1996).

The National Gap Web site may be found online at <http://gapanalysis.nbii.gov/portal/server.pt>. The WDFW Web site can be found online at <http://wdfw.wa.gov/wlm/gap/dataprod.htm>. The Washington GAP Web site is online at <http://depts.washington.edu/natmap/>.

Monitoring

Monitoring efforts and data derived from them in the Puget Sound Basin include monitoring-station locations, permanent and semipermanent gauges, in place transect-data collection, remotely sensed data interpretation, and other data sources. These datasets include monitoring programs put in place by State, local, Federal, Tribal, multi-agency and academic entities (table 4).

This section of the report is organized by using the categories defined by the Puget Sound Assessment and Monitoring Program's core activities (PSAMP, 2008). The monitoring within the Puget Sound cataloged here includes both marine and terrestrial programs, with a focus on the coastal zone. Each project or program listed contains general background information, the responsible agency, and the types of data and information products made available by the agency. Geospatial data are not part of all monitoring programs, and applicable data descriptions are used based upon what is available.

Table 4. Monitoring efforts at-a-glance.

[Project name, the date refers to the time period of monitoring data collection (note: the term present refers to the time of document publication, 2008), the spatial coverage of the monitoring initiative and extent (1=full; 0=partial) and the agency or source responsible for the monitoring program (empty cells indicate where information was not available). Blank cells indicate where information was not available. PSAMP (Puget Sound Assessment and Monitoring Program); WDFW (Washington Department of Fish and Wildlife); NOAA (National Oceanic and Atmospheric Administration); WADNR (Washington Department of Natural Resources); SRFB (Salmon Recovery Funding Board); SRSC (Skagit River System Cooperative); PSMFC (Pacific States Marine Fisheries Commission); PRISM-UW (Puget Sound Regional Synthesis Model-University of Washington); WA DOH (Washington Department of Health); USGS (U.S. Geological Survey); USEPA (U.S. Environmental Protection Agency); USFS (U.S. Forest Service; NRCS (Natural Resources Conservation Service); NPS (National Park Service).]

	Project Name	Date	Coverage	Extent	Source
1	Sediment and Benthic Habitat Quality				
1a	PSAMP Marine Sediment Monitoring (Four Programs)	annually since 1989-present	30-40 sites Bay-, region-, and/or Puget Sound-wide	1	PSAMP and Ecology
1b	Denny Way/Lake Union CSO Control Project Sediment Monitoring Program	2006	16 stations	0	King County
1c	Duwamish/Diagonal Sediment Remediation	2004-2014		0	King County
1d	Intertidal Sediment Reconnaissance Survey	2004-2005	Dalco Passage, 18 stations	0	King County
1e	West Point Outfall Sediment Monitoring	2006	12-18 stations	0	King County

	Project Name	Date	Coverage	Extent	Source
2	Toxic Contaminants in Fish and Shellfish				
2a	Fish Component of PSAMP	1989-1999; 2001-present	Puget Sound	1	WDFW
2b	Ecotoxicology & Environmental Fish Health Program	1979-present	Puget Sound & Pacific Northwest	1	NOAA Fisheries Service
2c	Shellfish Tissue Monitoring	1997-2006 (bi-annual)		0	King County
3	Nearshore Habitats				
3a	Kelp Monitoring Data	1989-2004	Juan de Fuca	0	WA DNR
3b	Submerged Vegetation Monitoring Project (SVMP)	2000-2005	Puget Sound	0	WA DNR; PSAMP
3c	Eelgrass Stressor-Response Project	2000-2006	Hood Canal and San Juan Is.	0	WA DNR
3d	Biotic Community Monitoring (Intertidal)	1997-2001	South and Central Sound	0	WA DNR
3e	ShoreZone Inventory	1994-2000	Statewide	1	WA DNR
4	Abundance of Key Marine Fish Resources				
4a	Groundfish Monitoring and Assessment	1996	Puget Sound	1	WDFW
4b	SSHIAP, SalmonScape and SaSI	~1992-2002	WA state	1	WDFW
4c	Wild Salmon Population Monitoring	1977-present; 2003-2005	approx. 20 trap sites across the state	0	WDFW
4d	Intensively Monitored Watersheds (IMW)	2003-present	Hood Canal, Strait of Juan de Fuca, Lower Columbia	0	Multi-agency
4e	Status and Trends Statewide Monitoring Framework (Salmon Recover Funding Board)	2005	Statewide	1	SRFB
4f	Skagit River System Cooperative Salmon Research	1993-present	Skagit River, delta, and bay	0	SRSC
4g	StreamNet: Fish Data for the Northwest	2000-05	WA state	1	PSMFC
5	Abundance of Key Marine Bird Species				
5a	Marine Bird Density Atlas	1992-2006	Puget Sound	1	WDFW-PSAMP
5b	Scoter Satellite Telemetry Project	2003-2006	Puget Sound	1	WDFW-PSAMP
6	Marine Water Quality				
6a	EMAP Estuary (Coastal) Station Locations	1999-2000	Statewide	1	USEPA
6b	Puget Sound CTD (Conductivity-Temperature-Depth) Profile Data	1999-2000	Central Puget Sound	0	King County

	Project Name	Date	Coverage	Extent	Source
6c	High Frequency, Real Time Puget Sound Water Quality Monitoring	2005-present	Seattle Aquarium, Denny Way in Elliott Bay, and Inner Quartermaster Harbor	0	King County
6d	Routine Offshore Water Column Monitoring Program	2006	Central Puget Sound	0	King County
6e	Moorings: Continuous Marine Water Data From Fixed Moorings	2005-present	Budd Inlet, Squaxin Passage, and Clam Bay	0	Ecology
6f	Focused Studies - South Puget Sound	1998-2000	South Puget Sound	0	Ecology
6g	PSAMP Marine Flights (long-term marine water quality data)	1973-present	Puget Sound	1	PSAMP
6h	PRISM Cruises: Marine Waters Monitoring	1998-2004	Puget Sound	1	PRISM-UW
7	Shellfish and Harvest bed conditions				
7a	DOH Shellfish Programs	Current	Statewide	1	WA DOH
8	Freshwater Quality				
8a	NAWQA sample sites (GW & SW)	1991-2007	Statewide	1	USGS
8b	Real Time Gages/Streamflow	real-time	Puget Sound Basin/U.S.	1	USGS
8c	USGS Lakes/Res Water Quality Samples	June 2005	Statewide	1	WA DNR
8d	EMAP Freshwater Monitoring	2000-2003			USEPA
8e	River and Stream Water Quality Monitoring	1959-present	Statewide	1	Ecology
8f	River and Stream Flow Monitoring	varies	Statewide	1	Ecology
8g	Water Temperature Assessment in WA State	varies	Statewide	1	Ecology
8h	Lake Water Quality Monitoring	1989-1999; 2007	60 lakes annually	0	Ecology
9	Land-based Sampling				
9a	Forest Inventory and Analysis (FIA)	1988-1997	Puget Sound Basin	1	USFS
9b	Region 6 Ecology Program	1979-present	National Forests	0	USFS
9c	Snowpack Monitoring	1979-2008	Puget Sound Basin	1	NRCS
9d	Glacier Monitoring	1950s-2005	South Cascade Glacier	0	USGS
10	Invasive Plant Species Inventories				

	Project Name	Date	Coverage	Extent	Source
10a	State and County Datasets	varies	Varies	0	varies
10b	USFS Invasive Plant Inventory	1990-present	National Forests	0	USFS
10c	Pierce County Invasive Plant Data	2007	Nisqually (WRIA 11)	0	Pierce County and partners
10c	Thurston County Invasive Plant Data	1975-2007	Thurston County	0	Thurston County Noxious Weed Control Program
10c	Mt. Rainier Park Exotics Inventory	2006	Mt. Rainier NP	0	NPS
10c	Gifford Pinchot National Forest		Gifford Pinchot NF	0	USFS

Sediment and Benthic Habitat Quality

Monitoring efforts on sediment and benthic habitat quality in the Puget Sound are performed by Ecology, Puget Sound Assessment and Monitoring Program (PSAMP), and King County.

Puget Sound Assessment and Monitoring Program Marine Sediment Monitoring

As part of PSAMP, Ecology's Marine Sediment Monitoring Team conducts annual monitoring of Puget Sound sediments. Goals that were set for the program by PSAMP in 1997 include the following components:

1. Assess the health of Puget Sound and its resources, as well as document geographic patterns in the condition of the Sound and its resources.
2. Document natural- and human-caused changes over time in the ecological components of Puget Sound.
3. Through ongoing monitoring programs, identify existing environmental problems and, where possible, identify the reasons for these problems.
4. Provide data and other information to assist the Puget Sound Partnership and others in measuring the success of environmental programs.
5. Support research activities by making available scientifically valid data.

Ecology and PSAMP's marine-sediment monitoring component has included four programs, past and present:

(1) [Historical Program](#), 1989-1995: collected sediment from 76 stations throughout Puget Sound, Hood Canal, and the Strait of Georgia. Thirty-four stations were sampled annually, while 42

stations were sampled on a 3-year rotation. The majority of these stations were purposefully located at a distance from known sources of contamination. Sediments were analyzed for chemical contamination, levels of toxicity, and the structure of sediment-dwelling invertebrates at each station. The historic program can be found online at

<http://www.ecy.wa.gov/programs/eap/psamp/HistoricalProfiles/historicalprogram.htm>.

(2) **NOAA partnership**, 1997-1999: surface sediment (upper 2-3 cm) was sampled from 300 random locations throughout Puget Sound. Samples were analyzed for acute toxicity in four laboratory tests, concentrations of more than 150 chemical parameters, and the community structure of sediment-dwelling organisms. Standardized methods, quality assurance, and quality-control methods were applied for this program's survey. The NOAA partnership can be found online at

<http://www.ecy.wa.gov/programs/eap/psamp/PSAMPNOAA/PSAMPNOAA.htm>.

(3) **Long Term/Temporal Monitoring**, 1989-present: conducts long-term monitoring at ten stations from the original historical program to provide a record of past and present sediment monitoring of chemical concentrations (5-year intervals) and the structure of infaunal macroinvertebrate communities (annually). The ten stations are in a range of habitats and geographic locations throughout Puget Sound, Hood Canal, and the Strait of Georgia. The long term/temporal monitoring can be found online at <http://www.ecy.wa.gov/programs/eap/psamp/TemporalMonitoring/Temporal.htm>.

(4) **Spatial/Temporal Monitoring**, 2002-present: after the PSAMP-NOAA partnership Ecology's Marine Sediment Monitoring Team revised the spatial sediment monitoring program to include a more refined probabilistic sampling design and a temporal element for quantification of large-scale regional changes in sediment quality over time. The sampling design includes eight monitoring regions that are sampled on an annual rotational cycle (40 sediment samples per region) beginning in 2004 with 2 years of focused embayment sampling between each 8-year cycle. Tables and maps of the sampling design and schedules can be found on the program's Web site. The spatial/temporal monitoring can be found online at <http://www.ecy.wa.gov/programs/eap/psamp/SpatialMon/Spatial.htm>.

Raw sediment sampling data is available on the programs' websites as MS Access databases. Results and publications from the programs also are available in PDF format from their publications Web site (http://www.ecy.wa.gov/programs/eap/psamp/PSAMPMsedMon/Ecology-PSAMP%20Publications_files/EcolPSAMPPubs.htm).

Puget Sound Sediment Monitoring Sampling Programs of King County

King County has several projects that assess sediment quality at wastewater and combined sewer overflows (CSO) marine outfalls in King County's marine waters.

Denny Way/Lake Union CSO Control Project Sediment Monitoring Program conducts sediment monitoring at the location of a finished construction site for a King County and City of Seattle project to control combined sewer overflows (CSOs) into Lake Union and Elliott Bay. The post-operational sediment sampling of surface sediments began in 2006 from 16 stations. The samples were analyzed for sediment chemistry and benthic infauna.

Duwamish/Diagonal Sediment Remediation project is part of the Elliot Bay/Duwamish Restoration Program (EMDRP). Contaminated sediment was isolated, and there is currently a 10-year monitoring program that began in 2004 after the remediation was completed. The site is within the southern industrial section of Seattle, in the lower portion of the Duwamish Waterway.

Intertidal Sediment Reconnaissance Survey was implemented in response to the Dalco Passage Oil Spill on October 14, 2004. The sediment analysis and results are described in a 19-page [report](http://dnr.metrokc.gov/Wlr/waterres/marine/reports/dalco-passage-oil-spill-report.htm) prepared by the King County Department of Natural Resources and Parks Marine and Sediment Assessment Group. The report includes a description of the survey, sampling and analytical methodology, and the results of the sediment chemistry analysis (<http://dnr.metrokc.gov/Wlr/waterres/marine/reports/dalco-passage-oil-spill-report.htm>).

West Point Outfall Sediment Monitoring is a National Pollutant Discharge Elimination System (NPDES) required sediment sampling and analysis at the West Point outfall in Seattle. Sediment samples were collected from at least 12 stations for analysis of Sediment Management Standards (SMS) chemicals of concern and conventional parameters.

Toxic Contaminants in Fish and Shellfish

Monitoring of toxic contaminants in fish and shellfish in the Puget Sound are performed by the WDFW and NOAA's Northwest Fisheries Science Center.

WDFW Fish Component for PSAMP

WDFW's Fish Component research for PSAMP evaluates the status and trends of chemical contamination in Puget Sound fish and macroinvertebrates. The study is designed to monitor five environmental indicators: (1) contaminant levels in tissue and bile, (2) liver disease in adult English sole, (3) endocrine disruption in male fish, (4) spawning success, and (5) fish abundance.

For each species monitored, there are three types of studies performed: Baseline Assessment Studies (table 5), Focus Studies, and Pilot Studies. Baseline Assessment Studies are used to examine temporal trends in contaminant exposure. Focus Studies are used to characterize the spatial pattern (for example, areal extent) of contaminant exposure for specific geographic locations. Pilot Studies are used to gather data to test hypotheses of proposed Baseline Assessments and Focus Studies. Pilot studies are usually carried out as a preliminary step when data are not already available in the literature.

Recreationally and commercially important species of fish and crabs are monitored throughout the Sound. Toxics exposure in the species monitored is assessed by measuring contaminants directly from fish tissues, metabolites of contaminants in fish, and health-effects, such as cancer or reproductive impairment.

For more detailed information on the study design, sample location sites, life histories of species monitored, and contaminants monitored see WDFW's PSAMP Web site (<http://wdfw.wa.gov/fish/psamp/index.htm>). Raw data is not readily available online; however, data summaries are available in a PDF report format for research and results done between 1989 and 1999.

Table 5. WDFW-PSAMP Fish component monitoring overview, including baseline station locations, temporal extent of data collection, and contaminants monitored for baseline assessment studies.

Species monitored	Baseline station locations	Temporal extent	Monitored contaminants
Rockfish species	Elliott Bay, Commencement Bay, Sinclair Inlet	1990-2001 bi-annually	Bile FACs (PAH metabolites), Chlorinated Aromatic Hydrocarbons, Conventional (lipids, protein, solids), Metals (mercury, lead), PCBs, Pesticides (DDD, DDT, DDE).
English sole	Strait of Georgia, Vendovi, Port Gardner, Hood Canal, Sinclair Inlet, Elliott Bay, Nisqually	Annually 1989-99; bi-annually since 2001	
Pacific herring	Semiahmoo Stock (north), Port Orchard (central), Squaxin Pass (south)	1995 Pilot Study; annually since 1999	
Salmon species (Coho and Chinook)	Nooksack, Skagit, Duwamish, Nisqually, and Deschutes Rivers	Bi-annually since 1990	
Staghorn sculpin	Puget Sound		
Dungeness crab	Puget Sound	2001	

National Oceanic and Atmospheric Administration Fisheries Ecotoxicology and Environmental Fish Health Program

The Northwest Fisheries Science Center conducts the Ecotoxicology and Environmental Fish Health Program as part of their Environmental Conservation Division in order to determine the impacts of human activities on the health of wild fish, especially Pacific salmon and marine fish. The program has five categorical research teams: Hazard Assessment and Risk Modeling, Immunology, Fish Neurobiology and Development, Pathology, and Reproductive Toxicology.

Since 1979, the program has written more than 200 journal articles, book sections, technical memorandums, reports, and a thesis about their research. A listing of their publications can be found on their publications Web site

(<http://www.nwfsc.noaa.gov/publications/displayinclude.cfm?incfile=ecbydoctype.inc>). A large amount of these publications are about studies and analyses that are Puget Sound-wide.

King County Shellfish Tissue Monitoring

Ambient and point-source (outfall) monitoring of bioaccumulation of pollution in bivalves (butter clams) in marine waters has been performed semiannually since 1997 by King County. The summaries, results, and data tables from these analyses are a part of the county's Puget Sound Water Quality Reports. Most years the collected shellfish are analyzed for lipids, metals, semivolatile organics, pesticides, PCBs, and bacteria (for example, fecal-coliform).

Nearshore Habitats

Monitoring efforts on nearshore habitats in the Puget Sound are performed by the Nearshore Habitat Program of the WA DNR, WDFW, and PSAMP.

ShoreZone Inventory

The ShoreZone Inventory was created by the WA DNR Nearshore Habitat Program (as well as by the WDFW and the Puget Sound Water Quality Action Team) and was published in 2001.

The ShoreZone Inventory dataset contains information about Washington States saltwater shoreline, compiled between 1994 and 2000 by using the ShoreZone Mapping System (Berry and others, 2001).

Inventory information was collected from a helicopter during low tides. Video imagery of the shoreline was recorded, along with location information (GPS). From the helicopter, a geomorphologist

and a marine ecologist recorded continuous commentary on the physical and biological features along the shoreline. Following the survey, the videotapes were taken back to the office for interpretation and classification. The geomorphologist divided the shoreline into units on orthophoto maps and described each unit. Next the marine ecologist added information on the living resources in each unit. The average unit length is 0.5 mile (Berry and others, 2001). Note: The accuracy of ShoreZone attributes has not been quantified.

The inventory covers all of Washington's saltwater shorelines, from the Canadian border to the mouth of the Columbia River. Features such as eroding cliffs, sand and gravel beaches, sandflats, and wetlands are some of geomorphic forms mapped. Visible macrobiotic, such as wetland grasses, intertidal algae, and subtidal vegetation, such as eelgrass or kelp, also are mapped.

These data are in linear ESRI shapefile format and a state-plane projection. A User's Manual and Data Dictionary are included as PDF files. The entire dataset is 54 MB. Layers in the dataset include:

1. Shoreline Characteristics

- Shoreline Type: Rock cliff, Rock platform, Rock with gravel beach, Rock with sand and gravel beach, Rock with sand beach, Channel, Gravel beach, Gravel flat, Sand and gravel beach or flat, Sand beach or flat, Mud flat, Estuary wetland, or Man-made (fig. 29).
- Substrate Type: Rock; Rock, gravel, and sand; Gravel; Gravel and sand; Sand; Mud and fines; Man-made
- Shoreline Modification: in percent modification (less than 5 percent to more than 95 percent)
- Exposure Class: Very protected, very exposed, semi-protected, semi-exposed, protected, and exposed.

2. Nearshore Vegetation

- Seagrass: Continuous, Patchy and Absent for Seagrass (all types), Surfgrass, and Eelgrass.
- Kelp: Continuous, Patchy and Absent for Kelp (all types), Floating and Non-floating Kelp.
- Sargassum: Continuous, Patchy and Absent
- Dunegrass: Continuous, Patchy and Absent
- Salt Marsh: Continuous, Patchy and Absent

3. Full Inventory Dataset

- ShoreZone Lines (szline)
- ShoreZone Polygons (szpoly)
- ShoreZone Points (szpt)

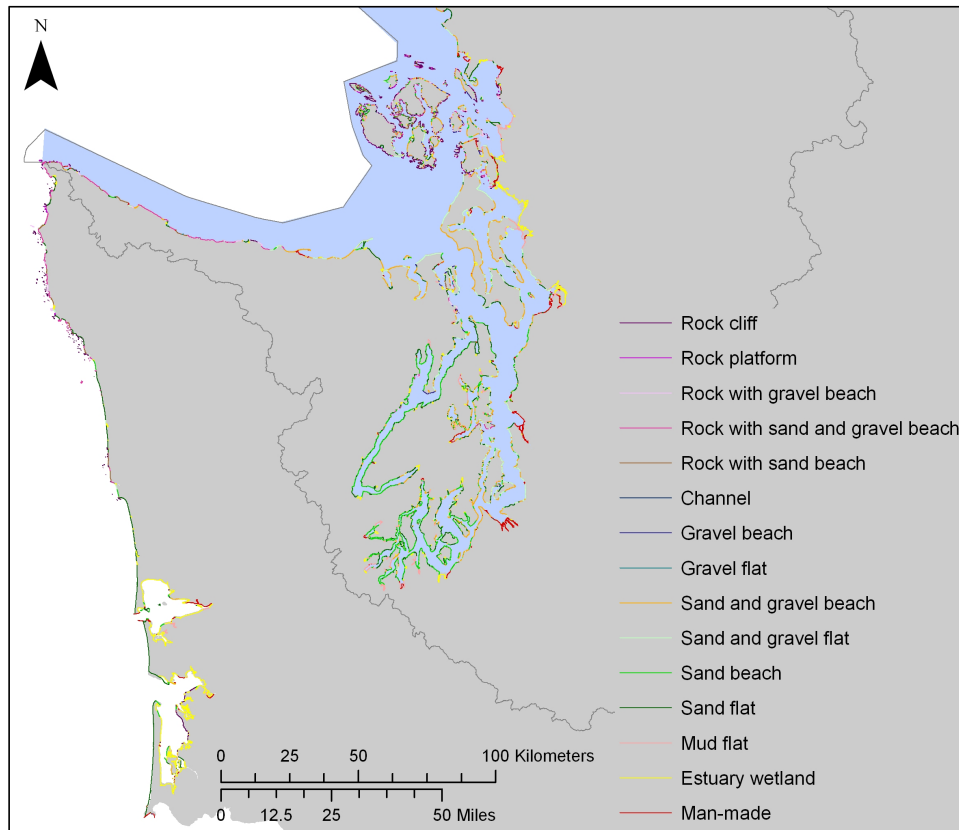


Figure 29. Map of the Shoreline Type of the ShoreZone Inventory for the Puget Sound and the coast of Washington.

B. Kelp Monitoring—Strait of Juan de Fuca (1989–2004)

These kelp-monitoring data were produced by the WA DNR Aquatic Resources Division’s Nearshore Habitat Program and were published in 2005. The data are in polygon ESRI shapefile format, are 40 MB, and are in a state-plane projection.

The kelp-monitoring dataset includes maximum bed extent of floating kelp along the Strait of Juan de Fuca and Outer Coast (fig. 30) during the study period, defined by floating kelp-bed area data for all inventory years (1989-1992 and 1994-2004). These data include two species of floating kelp, *Nereocystis luetkeana* and *Macrocystis integrifolia*. Data were derived from photo interpretation of low-tide aerial photography in the late summer. Polygons represent bed area, which includes the kelp canopy floating on the surface and small gaps between the plants (25-meter threshold).

These data are part of a long-term monitoring effort. The entire dataset is comprised of the following files: yearly inventory files from 1989 through 2004, excluding 1993 (kelpYYYY.shp), combined inventory from all years (kelp1989_2004.shp), and a geodatabase (map_index.mdb)

containing a spatial index (map_index.shp) and tabular information describing kelp characteristics for each year that link to the spatial index (kelp_mon.dbf).

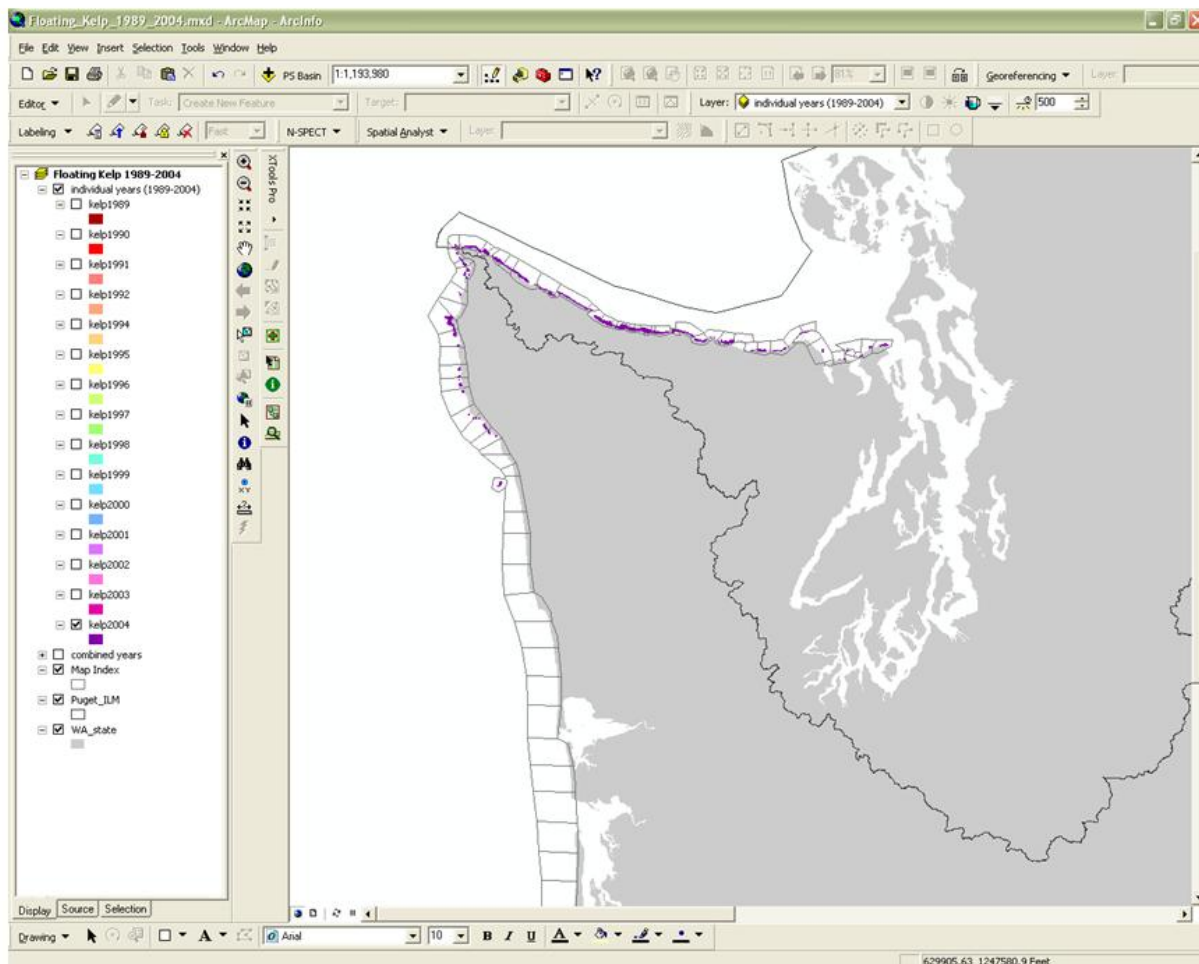


Figure 30. Screen capture of kelp-monitoring data in ArcMap.

Eelgrass Monitoring

The Submerged Vegetation Monitoring Project (SVMP) by the WA DNR has conducted annual surveys of eelgrass (*Zostera marina*) abundance and distribution throughout the Puget Sound from 2000 to present (2008). A large portion of the SVMP is change analysis conducted between years. The methods, analysis, process, and results of the SVMP surveys are documented in downloadable reports from their [Web site](http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_monitoring.aspx) (http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_monitoring.aspx).

At each sample site (fig. 31), a minimum of 11 random transects are sampled by using underwater videography. The video sampling resolution is nominally one square meter and *Z. marina* is categorized as being present or absent based on the observation of rooted shoots within the video field of view. The fractional cover of *Z. marina* along transects is used to calculate the area of *Z. marina*. The depth at which *Z. marina* grows along each transect is used to estimate mean maximum and minimum depth of *Z. marina* relative to Mean Low Low Water (MLLW) at each site and within each region (Gaeckle and others, 2007).

Measured parameters of the SVMP are shown in table 6. Plant characteristics include shoot density, leaf width, and leaf length. Both plant characteristics and water quality measurements were terminated after the 2002 field year due to limitations of these data for the scope of the study (Dowty and others, 2005).

Table 6. Submerged Vegetation Monitoring Project (SVMP) survey parameters.

Parameters Survey report years	Temporal extent	Abundance area	Min/max depth	Plant characteristics	Water quality	Bed patchiness
2000-2002	June-Oct.	x	x	x	x	x
2003-2004	June-Sept.	x	x			x
2005	June-Sept.	x	x			x

monitoring results, which can be found on the project's Web site

(http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_stressor_response.aspx).

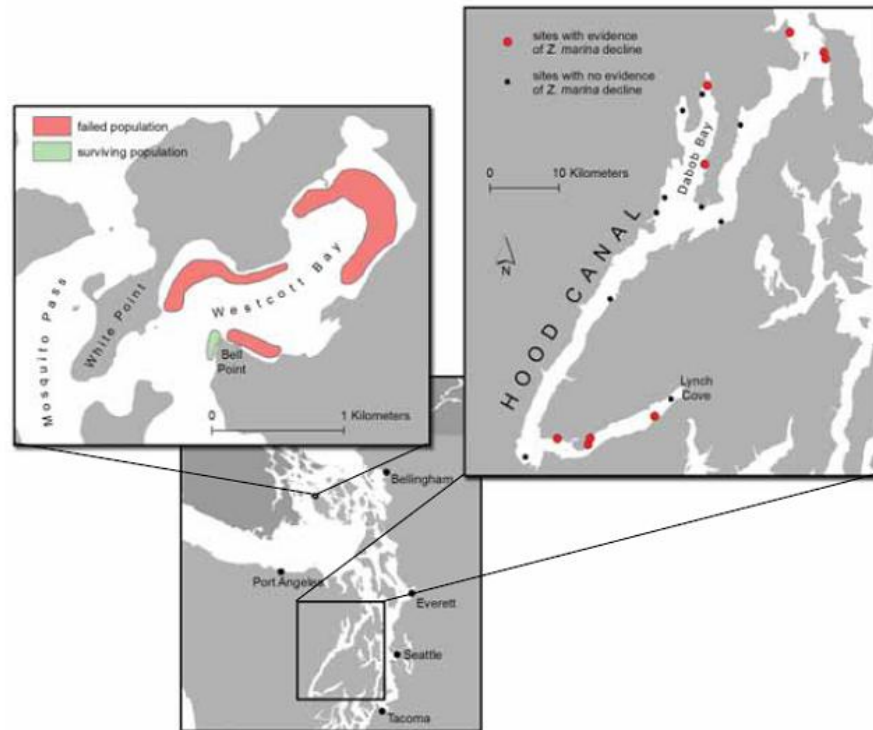


Figure 32. Map of the focus areas from the first Eelgrass Stressor-Response Project (Dowty and others, 2007).

Intertidal Biotic-Community Monitoring

The Nearshore Habitat Biotic Community Monitoring program is a cooperative effort between the WA DNR Nearshore Habitat Program, the University of Washington's Department of Zoology, and the University of Alaska, Fairbanks. This study has performed annual monitoring of intertidal biota on beaches in central and southern Puget Sound since 1997.

The project goals are: 1) to collect baseline information on community patterns in Puget Sound; 2) to determine if the intertidal biological community is a suitable indicator of habitat condition for PSAMP; and 3) to provide large-scale, contextual information for comparison to more detailed studies. The biological community-monitoring project samples organisms living on and in the substrate in the lower intertidal zone. In 1997, samples were collected in Carr Inlet. Since then, the geographic extent of the project has gradually expanded to include Case Inlet, Budd Inlet and Central Sound, Washington.

Sampling employs 50-meter horizontal beach transects with a collection of 10 random samples along each transect. Each sample consists of quantifying surface macroflora and fauna and infauna in a 10-cm core dug to 15 cm depth. The study produces annual project reports that contain detailed descriptions of methods used, sites sampled, statistical analyses completed, and conclusions.

Collaborative Projects with the Intertidal Biotic Community Monitoring include the SCALE project (Shoreline Classification and Landscape Extrapolation) and the Shoreline Diversity Patterns in Puget Sound with the University of Washington and the Washington Sea Grant program.

Abundance of Key Marine-Fish Resources

Monitoring efforts on the abundance of key marine-fish resources in the Puget Sound are performed by WDFW, the Salmon Recovery Fund Board (SRFB) supported by the Washington State Recreation and Conservation Office, and the Skagit River System Cooperative (SRSC) on behalf of the Sauk-Suiattle Indian Tribe and the Swinomish Indian Tribal Community for their fisheries management.

Groundfish Monitoring and Assessment

In the past, measured conditions of groundfish populations in Puget Sound have been dependent on how well fisheries perform, both recreational and commercial. When groundfish populations began to decline and restrictions were put on certain fisheries, it became difficult to measure populations with a fishery-dependent model. The WDFW began to conduct fishery-independent surveys of fish populations in 1987 (Puget Sound Action Team, 2007). Surveys now employ bottom trawls, diving, and remote optical tools to determine the condition of rockfish, lingcod, flatfish, dogfish, and cod populations in Puget Sound (Puget Sound Assessment and Monitoring Program, 2008).

The monitoring of groundfish in the Sound by WDFW is now conducted with a combination of fishery-dependent and independent sources. These data determine long-term trends and the current status of populations in Puget Sound. Several data-collection systems exist and differ among fishery. Due to population declines, the Washington Fish and Wildlife Commission (now, WDFW) adopted the Puget Sound Groundfish Management Plan (PSGMP) in 1996, in order to maintain healthy populations of groundfish in Puget Sound inner-marine waters. The Management Plan is available online at <http://wdfw.wa.gov/fish/grndfish/grndfish.htm>.

Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP), Salmonid Stock Inventory (SaSI), and SalmonScape

The Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) maintains a spatial data system that describes salmonid habitat conditions and distribution of salmonid stocks in Washington at a scale of 1:24,000. The SSHIAP is co-managed by the WDFW and the Northwest Indian Fisheries Commission (NWIFC). The basis of the SSHIAP data system is a cleaned and routed hydrography layer, which is used to integrate a wide variety of habitat information and analysis. SSHIAP data can be viewed and downloaded from SalmonScape (see below).

The WDFW hosts an online, interactive mapping application, [SalmonScape](#), that provides a wide range of data related to salmon distribution, status, and habitats. The digital information provided by SalmonScape includes data collected by State, Federal, Tribal, and local biologists. Selected map layers (24k hydro, Stream Attributes, Stock Status, Fish distribution, EDT Restoration, EDT Preservation, Fishways, Fish Passage Barriers, Repaired Barriers, Other downloadable barriers) can be downloaded from the site in ESRI shapefile format in a state-plane projection along with metadata. Users of SalmonScape can query SaSI data for table and geospatial graphic output (fig. 33), depending on the data type returned, as well as reports, when available.

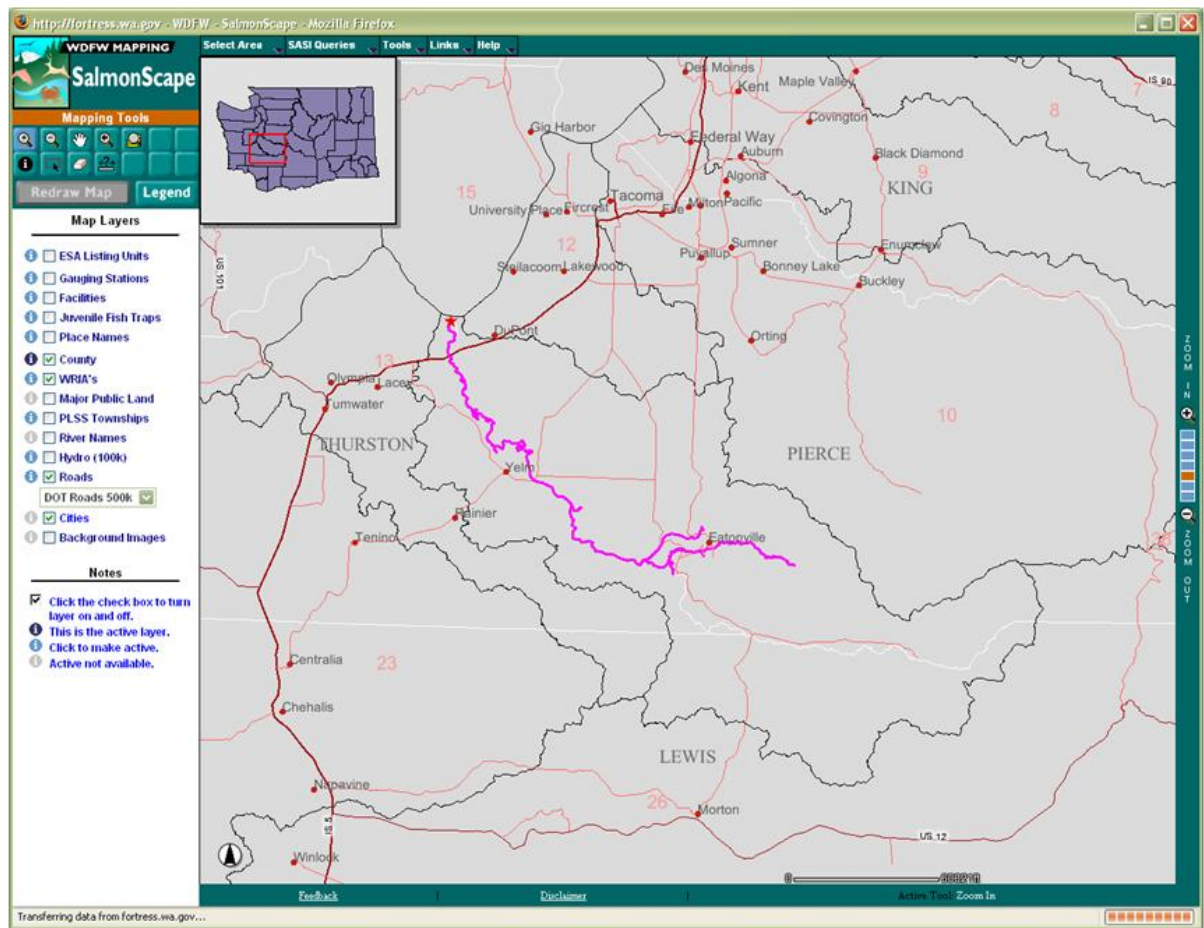


Figure 33. Screen capture of SalmonScape with the Nisqually Watershed (WRIA 11), Washington and stocks by area (SaSI) query displayed.

The Salmonid Stock Inventory (SaSI) is a collection of data on wild stocks and a scientific determination of each stock's status as: healthy, depressed, critical, unknown, or extinct. SaSI is a basis for prioritizing recovery efforts and for measuring the results of future recovery actions. It is a cooperative effort of the WDFW and tribal comanagers.

The SaSI rating process includes the analysis of stock-specific production trends. Currently, the screening criteria do not incorporate quantitative formulas since the available stock-specific information is often too limited and too variable for statistical evaluation.

A set of negative screening criteria are used to indicate when a stock is not healthy. A long-term negative trend is met when ten or more years of data show a decline in production. A short-term severe decline is met when there is a marked drop in production in at least two of the last five years. A

chronically low trend is met when production is not exhibiting a negative trend, but is consistently below a stock's potential production. Stocks that meet none of the criteria and whose production is determined to be within the natural range are rated as healthy (Salmonid Stock Inventory, 2002).

The status of some Puget Sound Chinook stocks were rated by using habitat-based recovery goals developed by NOAA fisheries, WDFW, and Puget Sound Treaty Tribes and is described in the Introduction section of the SaSI 2002 Stock Report

(http://wdfw.wa.gov/fish/sasi/sasi_2002_introduction.pdf).

Queries of SaSI data that can be accessed by using SalmonScape (see above) include Stocks by Status and Species, Stocks by Area, Status Summary by Species, and Status Summary by Production Type.

Wild Salmon Population Monitoring

In 1977 the Wild Salmon Production Evaluation unit (WSPE) was created to measure production, survival, and fisheries contribution of wild salmon stocks in Puget Sound, the Washington coast, and lower Columbia River. Since its creation, WSPE has continued to enumerate adult and smolt populations in these regions.

The wild salmon populations are monitored for harvest and habitat management, to inform the restoration process, to assess effects from shoreline development and lake management, to evaluate influences by hydropower and/or water management, and to monitor production and catch. Currently, the WDFW monitors downstream-migrant production in several large- and small-stream systems (fig. 34).

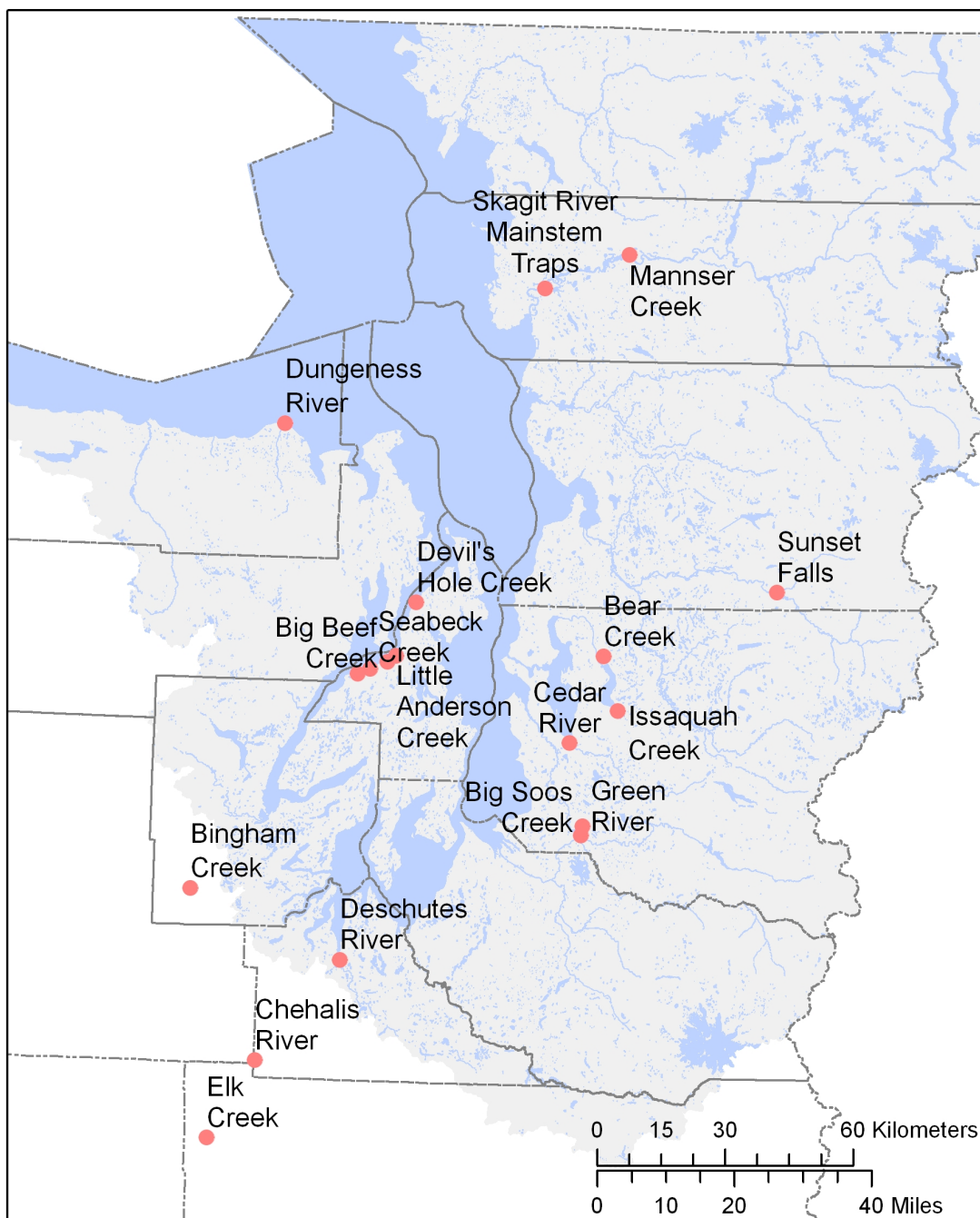


Figure 34. Map of Washington Department of Fish and Wildlife (WDFW) wild-salmon population-monitoring trap sites in the Puget Sound Basin.

In 1977, the WSPE began monitoring adult Coho salmon. Since then, WSPE studies have collected more than 20 years of continuous measurements from Big Beef Creek (Hood Canal), the Deschutes River, and Bingham Creek (Chehalis River).

More recently, the monitoring focus has expanded to include additional anadromous species in a variety of watersheds (table 7). The locations of traps and distributions of wild salmonids throughout Washington can be found on the WDFW's *Salmonscape* Web site (<http://wdfw.wa.gov/mapping/salmonscape/>).

Table 7. Watersheds currently monitored for their wild salmon populations by the Washington Department of Fish and Wildlife (WDFW) includes the species, temporal extent, and data products derived from the monitoring efforts.

[Data and reports can be found online in Microsoft Excel and PDF formats at the URLs below.]

Watershed	Species (historical and current)	Temporal extent	Data and reports
<i>Skagit River</i> ¹ (near Mount Vernon)	Coho (1990), Chinook (1995)	1990–present	2006 dataset: catch, trap calibration and size for Chinook and Coho captured at the mainstem trap and Mannser Creek weir (xls); 2006 Report
<i>Lake Washington</i> ² : Cedar River	Wild and hatchery sockeye salmon (1992), Chinook, Coho, steelhead, and cutthroat (1999)	1992–present	Several publications
<i>Lake Washington</i> ² : Big Bear Creek	Downstream migrant salmon (Chinook, sockeye)	1997–1998 (Sammamish Slough); 1999–present	Several publications
<i>Green River</i> ³ (near Auburn)	Chinook	2000–present	2003/6 dataset: catches, trap calibration for 2003/5 and 2006 (preliminary), and size data for Coho, Chinook & steelhead; and several reports.
<i>Deschutes River</i> ⁴	Chinook and Coho	1977–2002	2002 Index Watershed Salmon Recovery Monitoring Report
<i>Hood Canal</i> ⁵ (Stavis, Seabeck, Big Beef, and Little Anderson, Devil's Hole Creeks)	Coho	1977–present	Publications and Data by creeks/streams. Currently, all four streams are being monitored as part of the Intensively Monitored Watersheds (IMS) project.
<i>Dungeness River</i> ⁶	Chinook	2005–present	2005/6 catches, size data for Chinook, Coho, steelhead & chum, Preliminary trap calibration in 2005 and 2006 (preliminary)

¹http://wdfw.wa.gov/fish/wild_salmon_monitor/skagit_river.htm.

²http://wdfw.wa.gov/fish/wild_salmon_monitor/lake_washington.htm.

³http://wdfw.wa.gov/fish/wild_salmon_monitor/green_river.htm.

⁴http://wdfw.wa.gov/fish/wild_salmon_monitor/deschutes_river.htm.

⁵http://wdfw.wa.gov/fish/wild_salmon_monitor/hood_canal.htm.

⁶http://wdfw.wa.gov/fish/wild_salmon_monitor/dungeness.htm.

Intensively Monitored Watersheds (IMW)

The Intensively Monitored Watersheds (IMW) project was implemented in 2003 by the WDFW, Ecology, and the Lower Elwha Klallam Tribe to determine the response of salmon populations to habitat restoration in a few selected watersheds. The project is currently being conducted in three well-studied areas: Hood Canal, Strait of Juan de Fuca, and Lower Columbia. The project focuses on a few locations in order to collect enough data on physical and biological attributes to detect and compare the effects of restoration treatments on Coho salmon, steelhead and cutthroat trout production in experimental treatment (restoration) and control (no restoration) watersheds.

The IMW agencies and partners have begun collecting water-quantity, water-quality, habitat, summer juvenile-fish abundance, and smolt-production data and are identifying specific restoration actions for each IMW treatment watershed, data from the USEPA's Environmental Monitoring and Assessment Program (EMAP) wadeable-stream protocol and WDFW also are used. Maps and charts displaying these data can be found on the *IMW Web site* (<http://wdfw.wa.gov/hab/imw/index.htm>).

The two watershed complexes in the Puget Sound Basin are Hood Canal (Stavis Creek, Big Beef Creek, Seabeck Creek, and Little Anderson Creek; fig. 35A) and Strait of Juan de Fuca (West Twin River, East Twin River, and Deep Creek; fig. 35B).

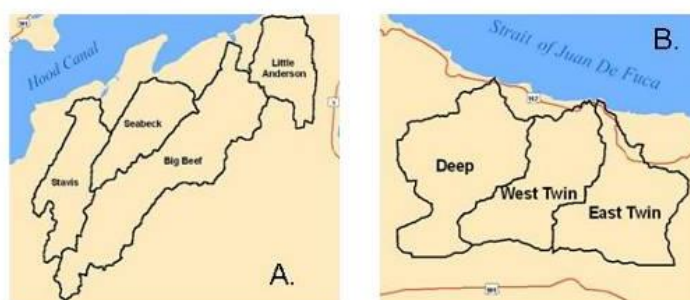


Figure 35. Maps of Intensively Monitored Watershed (IMW) complexes in the Puget Sound Basin: A, Hood Canal, and B, Strait of Juan de Fuca (WDFW, resolution due to screen capture).

Skagit River System Cooperative

The Skagit River System Cooperative (SRCS) is a natural-resource management agency working on behalf of the Sauk-Suiattle Indian Tribe and the Swinomish Indian Tribal Community. The Research Department at the SRSC collects and analyzes data on fish habitat use; fish response to recovery efforts, including habitat restoration; and linkages between habitat conditions, landscape processes, and land uses. The Research Department field crew collects fish-distribution data in the Skagit Bay and Skagit River delta (fig. 36) by using beach seines and fyke traps at regularly sampled sites and at one-time sampling sites that are randomly selected. Information on the fish caught includes identification, counts, and measurements. General habitat information recorded includes water temperature, depth, salinity, current velocity, substrate, and vegetation.

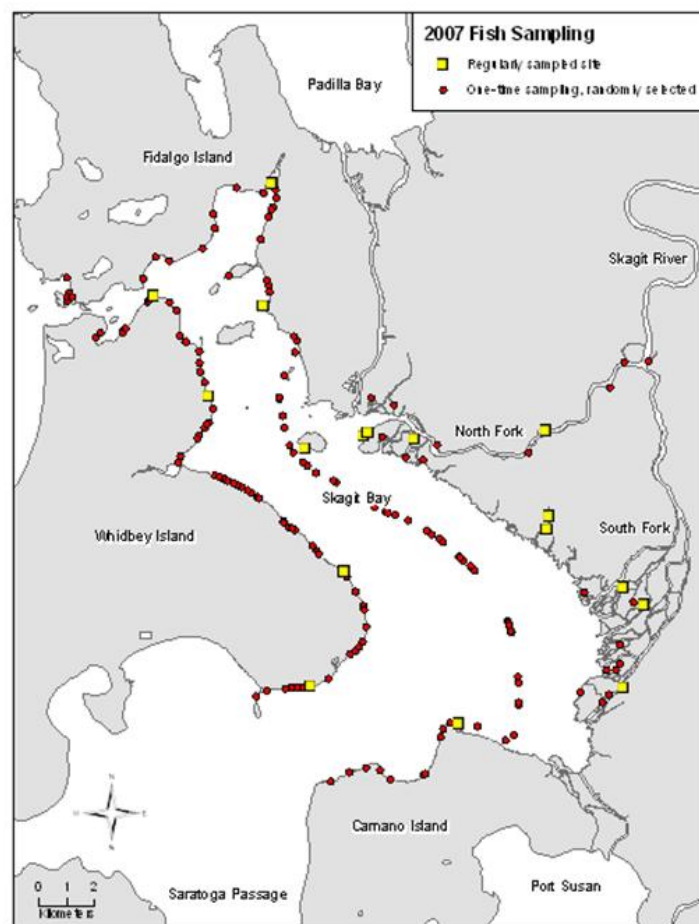


Figure 36. Map of the Skagit River System Cooperative 2007 Fish Sampling Sites in the Skagit Bay, Puget Sound, Washington. (SRSC, <http://www.skagitcoop.org/index.php/research/>).

StreamNet

StreamNet is a cooperative information management and distribution project focused on fisheries and aquatic-related data in the Pacific Northwest and the Columbia River Basin.

Types of geospatial data that are accessible for download from the StreamNet Web site include anadromous fish distribution, resident fish distribution, hydrography, water quality, fish passage barriers, facilities (hatcheries and dams), and boundary files (HUCs, subbasins, NOAA Evolutionary Significant Units). These data are in ESRI shapefile format and in a customized Lambert Conformal Conic projection.

StreamNet fish data also include a data store, library, map catalog, the 1:100,000 scale hydrography layer of the PNW, StreamNet database in Microsoft Access format, and online interactive mapping applications (table 8).

Table 8. List of StreamNet Interactive Mapping Applications and their related data that are available online at the StreamNet Web site.

Name	Data
Northwest Critical Habitat Mapper ¹	Critical habitat designations for 12 Evolutionarily Significant Units (ESU) of Pacific salmon and steelhead.
Pacific Northwest Mapper ²	Fish distribution data and the StreamNet database.
Columbia Subbasin Mapper ³	Similar to the Pacific Northwest Mapper but organized by the NW Power Planning Council provinces and subbasins.
Protected Areas Mapper ⁴	1988 Protected Areas (stream reaches protected from hydroelectric development) database.

¹<http://map.streamnet.org/criticalhabitat/viewer.htm>.

²<http://map.streamnet.org/snetmapper/viewer.htm>.

³<http://map.streamnet.org/subbasinmapper/viewer.htm>.

⁴<http://map.streamnet.org/protectedquery/viewer.htm>.

Status and Trends Statewide Monitoring Framework

The Status and Trends Statewide Monitoring Framework is a Salmon Recovery Funding Board (SRFB) project to develop a sampling plan that reports watershed status and salmon recovery efforts in

Washington State. The SRFB was created by the State legislature in 1999 and is supported by the Washington State Recreation and Conservation Office.

Status and Trends will be monitoring the condition of streams and rivers and using the monitoring data as a proxy for the condition of salmon and status of salmon recovery across the state at multiple spatial scales: WRIAs (fig. 19), Salmon Recovery Regions (fig. 36), and statewide. Results are not yet available for the Status and Trends project. Currently, plans and proposals for the project may be downloaded at <http://www.ecy.wa.gov/programs/eap/stsmf/>.



Figure 37. Map showing Salmon Recovery Regions in Washington (Washington State Department of Ecology, <http://www.ecy.wa.gov/programs/eap/stsmf/>, resolution due to screen capture).

Abundance of Key Marine Bird Species

Efforts to monitor the abundance of key marine-bird species in the Puget Sound are done by the WDFW and PSAMP.

Marine Bird Density Atlas

The WDFW and PSAMP host an online ArcIMS interactive mapping application that provides information on birds found on inland marine waters. Data on the marine birds and mammals is collected during WDFW-PSAMP winter and summer surveys. The Atlas includes marine-bird density data between the years of 1992 and 2006.

In 1991 through legislatively provisioned funds, the WDFW was given responsibility of designing and implementing monitoring plans for marine birds, waterfowl, and marine mammals under PSAMP. The study design was contracted out, and aerial surveys began in summer 1992. The avian-

abundance data collected during the aerial surveys are designed to be used as indices of spatial and temporal trends.

The surveys sampled the entire marine shoreline of greater Puget Sound by two strata, nearshore (less than 20 meters) and offshore (more than 20 meters). Annually, surveys covered 13-15 percent of the nearshore marine waters and 3-5 percent of the offshore marine waters in Puget Sound, up to the Canadian border and out to the entrance of the Strait of Juan de Fuca. The area covered by the summer survey was reduced, due to budget cuts, to the northern two-thirds of greater Puget Sound after the summer of 1997. The summer surveys were stopped after 1999, while the winter-survey coverage remained similar from 1993-2006.

Methods of the surveys include the use of a Dehaviland Beaver floatplane that flew at 80-90 knots (kt) at an altitude of approximately 65 meters above sea level. An on-board computer linked to a GPS unit recorded the time and position every 5-10 seconds. Two observers recorded all birds seen along a 50-meter-wide strip on each side of the plane along with observation times to be interpolated with the GPS track line by using a computer program.

A 2-minute grid is used to display the observation density within the online mapping application (fig. 38). The densities displayed on map products are those actually observed on transects, and they have not been treated with any correction factors for animals that may have been missed. Although it may be tempting to use these data to make population estimates, it is more appropriate to treat them as density indices that can be evaluated for trends over a number of years.

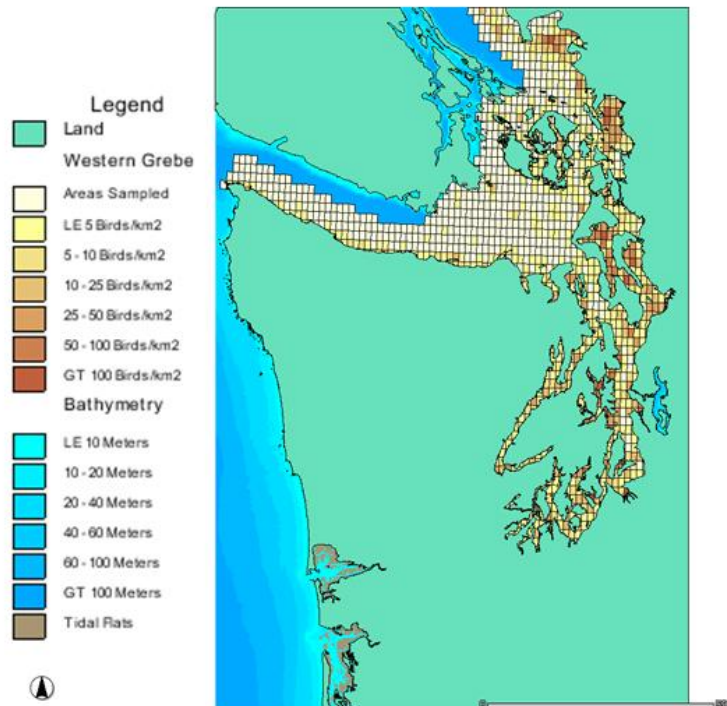


Figure 38. Example map from the Marine Bird Density Atlas, Western Grebe, Winter Surveys 1993-2006, Puget Sound, Washington. (Resolution due to screen capture.)

Scoter Satellite Telemetry Project in Puget Sound

In 2003, the WDFW, with funding from the Sea Duck Joint Venture, began a research project that captured and tracked migratory movements of White-winged Scoters (*Melanitta fusca*) and Surf Scoters (*M. perspicillata*) during the winters of 2003-2006.

The scoters were captured in the South Puget Sound (Henderson Inlet, Eld Inlet, and Peale Passage), Central Puget Sound (Greater Port Orchard/Bremerton area), and the Northern Puget Sound (Penn Cove, Oak Harbor, and Birch Bay). All captured birds were aged, sexed, measured, banded with stainless-steel bands, and recorded. Tissue and blood samples also were collected. Suitable scoters were transmitted with Satellite PTTs (Platform Transmitter Terminals; 2003-05) or VHF (very-high-frequency) transmitters (2004-05). In order to track the scoters, the data was transmitted from the PTT transmitters by the use of satellites to the project staff.

The satellite data results can be found online at <http://wdfw.wa.gov/wlm/psamp/scoters/index.htm>. Results include individual bird tracks for the White-

winged Scoters (2003-2005) and the Surf Scoters (2004 and 2005). Figure 39 displays all White-winged scoters tracks for 2003.

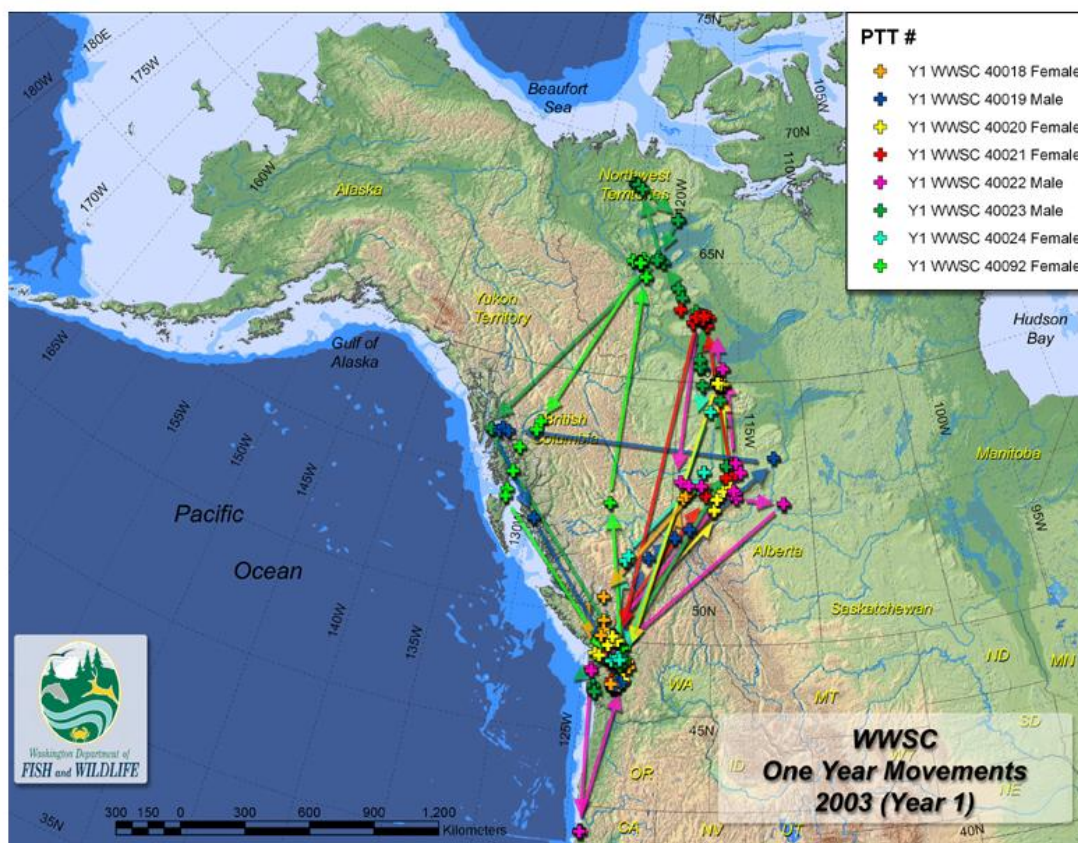


Figure 39. Map of satellite telemetry project results for all white winged scoters, Puget Sound, Washington. (Nysewander and others, 2005).

Marine Water Quality

Monitoring efforts for marine water quality in the Puget Sound are done by Ecology, King County, University of Washington's Puget Sound Regional Synthesis Model (PRISM) program, and the USEPA.

EMAP: Environmental Monitoring and Assessment Program, USEPA

EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. Western EMAP (Region 10) has 3 main components: coastal, rivers and streams, and landscapes. The objective of Western EMAP is to assess the ecological condition of coastal waters and rivers and streams across the western United States. EMAP is designed

to monitor indicators of pollution and habitat condition and to seek links between human-caused stressors and ecological conditions.

EMAP uses a random stratified sampling design that is described as a spatially balanced probabilistic survey design. Different years of the survey include different focus areas and sample sites. Small estuaries were sampled in 1999 and included the Strait of Juan de Fuca, but not the inland waters of the Puget Sound. In 2000, large estuaries were sampled in the Puget Sound. No sampling was done in Washington State in 2001. Intertidal sampling was done in the coastal areas and Puget Sound in 2002, and in 2003 offshore (continental shelf) samples were collected, with one sample collected in the western portion of the Strait of Juan de Fuca, which is included in the Puget Sound Basin and the PSILM study area.

The station-location data (fig. 40) are represented as points in ESRI shapefile format in a GCS and total 29 KB. The data present a record of where samples were taken at stations during the 1999 and 2000 projects on the west coast of the United States. Site-visit information includes the date and number of the sampling visit and the water depth at the time of the visit.

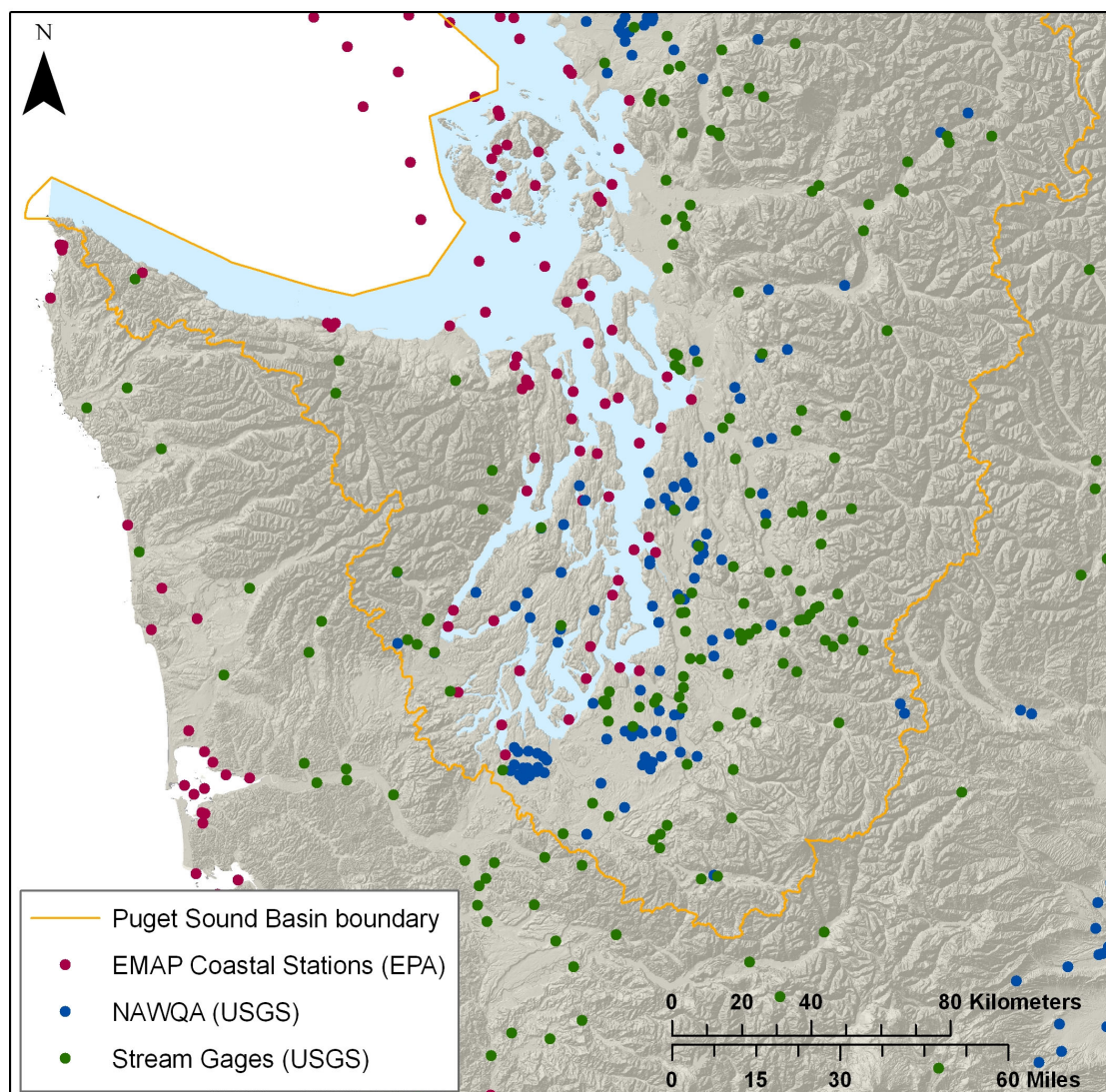


Figure 40. Map of Environmental Monitoring and Assessment Program, National Water-Quality Assessment, and U.S. Geological Survey streamflow-gaging station locations, Puget Sound, Washington. (USEPA and USGS).

Attributes of the spatial file include a Station Name, making it possible to join data collected on indicators at the stations (table 9). There are 162 stations on the Washington coast and 114 stations in the Puget Sound Basin.

Table 9. Selected EMAP coastal indicators (Source: Hayslip, 2006).

Water column	Sediment	Biological
Water clarity	Silt-clay content	Benthic organisms
Dissolved oxygen	Sediment contaminants	Fish-tissue contaminants
Dissolved nutrients	Sediment toxicity testing	
Total suspended solids		

Puget Sound Conductivity-Temperature-Depth (CTD) Profile Data, King County

King County Natural Resources and Parks Department Marine and Sediment Assessment Group does Offshore Water Column Monitoring by using a conductivity-temperature-depth (CTD) instrument. There are a number of stations that are either active or inactive at any time. In 2004 there were 11 active CTD stations: 6 outfalls and 5 ambient.

The parameters that are measured include temperature, salinity, water-column density (sigma-t), water-column dissolved oxygen, water-column chlorophyll-a, turbidity, pheophytin, and PAR (photosynthetically-active radiation).

Data may be downloaded, in Microsoft XLS or TXT format, by locator-station point (fig. 41), by individual or multiple parameters (above), and by a user-specified range of dates.

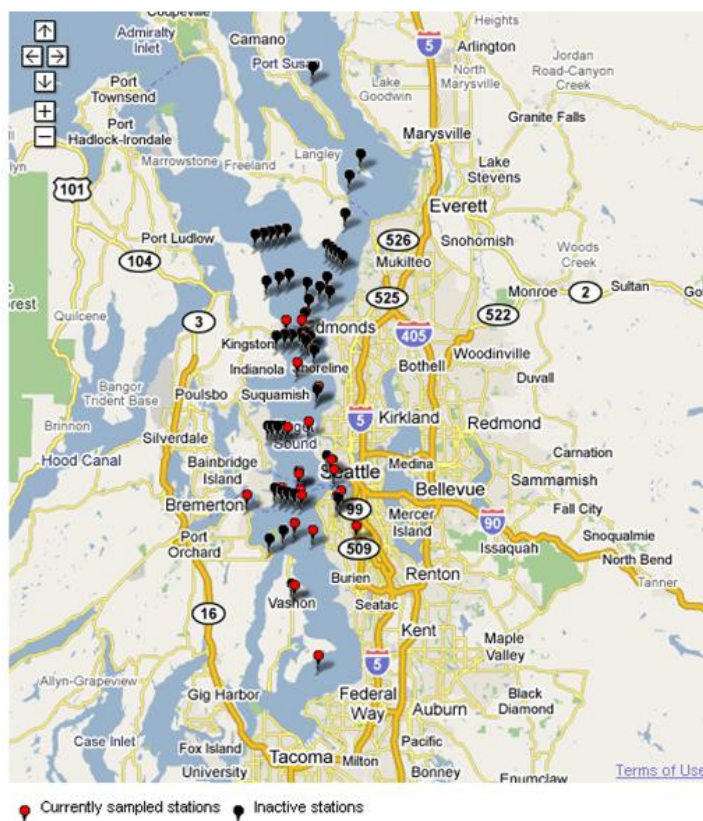


Figure 41. Screen capture of map of Puget Sound, Washington with King County's conductivity-temperature-depth (CTD) profile data sample points (resolution due to screen capture).

High Frequency, Real Time Puget Sound Water-Quality Monitoring

King County Natural Resources and Parks Department conducts a High Frequency, Real Time Puget Sound Water-Quality Monitoring program. The data is available online in real time from their three marine monitoring stations: Seattle Aquarium, Denny Way in Elliott Bay, and Inner Quartermaster (Yacht Club) Harbor (fig. 42).

Water-quality and meteorological data collected at the Seattle Aquarium station (and updated every 15 minutes) include:

- Water temperature (degrees Celsius)
- Water conductivity (microSiemens per centimeter)
- Water salinity (parts per thousand)
- Water pH
- Water depth (meters)
- Water chlorophyll concentration (milligrams per liter)
- Water turbidity (Nephelometric Turbidity Units)
- Water dissolved oxygen saturation level (percent)
- Water dissolved oxygen concentration (milligrams per liter)
- Solar radiation (Kilowatt per square meter)
- Precipitation (inches)
- Average wind direction (degrees)
- Average wind speed (meter per second)
- Air temperature (degrees Fahrenheit)
- Relative humidity (percent)

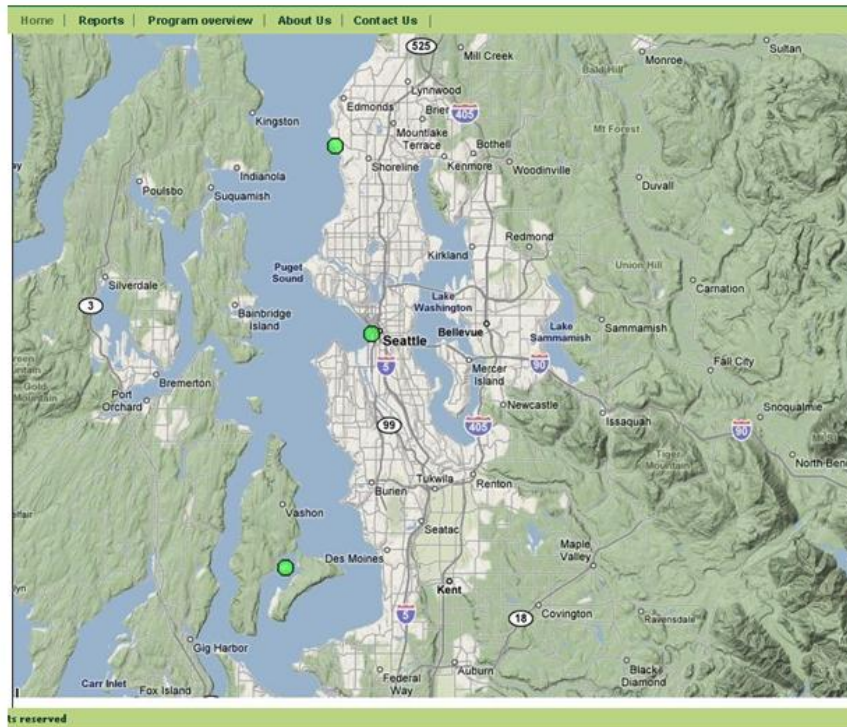


Figure 42. Screen capture of map of King County high frequency real time Puget Sound water-quality monitoring stations (represented by green circles).

The monitoring station at Denny Way collects only turbidity and oxygen data and is a temporary deployment. The Inner Quartermaster Harbor station collects water-quality and meteorological data.

Data may be downloaded in a report format from an interactive, online application (<http://www.ysieconet.com/public/WebUI/Default.aspx?hidCustomerID=165>). The user has the option to either download data from the previous week (Fixed Time Period Report), or define the time period (User Defined Time Period). Data reports can be viewed as HTML spreadsheets and/or exported as a .csv file.

Moorings: Continuous Marine-Water Data from Fixed Moorings

Ecology has 3 moorings deployed in the Puget Sound (fig. 43) collecting real-time data that is transmitted to a base station server for upload to the NANOOS (Northwest Association of Networked Ocean Observing Systems) pilot Web site (<http://www.ccalmr.ogi.edu/nanoos/>). Data plots may be viewed in certain (for example, 2-day, 7-day) time intervals; data are not yet available for direct download.

Data collected includes near-shore, near-bottom water temperature, salinity, density, and dissolved oxygen. The instruments transmit data in real-time to the NANOOS Web site, and historical data is available *upon request* (email sjae461@ecy.wa.gov).

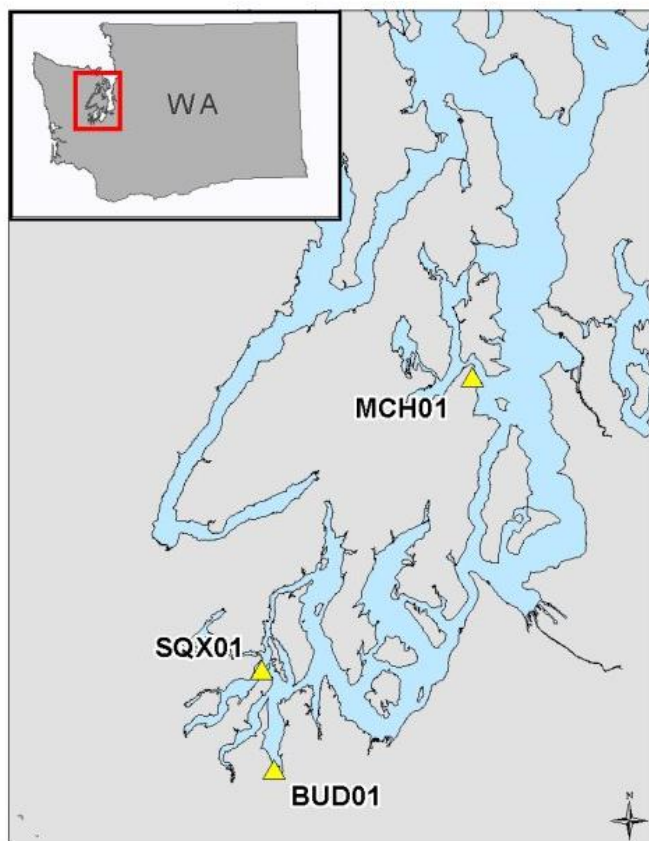


Figure 43. Puget Sound locations of Washington State Department of Ecology fixed moorings.

PSAMP Marine Flights: Long-Term Marine Water-Quality Data

Ecology's Marine Waters Monitoring program is designed to measure ambient water-quality conditions in Puget Sound and the coastal estuaries of Washington State. Long-term monitoring data are collected with the goal of detecting effects from human activities leading to contamination and/or habitat degradation. The water-quality monitoring is conducted from a DeHavilland Beaver floatplane, which allows a large geographic area to be sampled in a short amount of time.

There are 73 stations (26 "core" and 47 rotating); core stations are monitored each year on a monthly basis. Parameters monitored at the stations from the seaplane include profiles of temperature, salinity, density, dissolved oxygen, light transmission, pH, as well as discrete samples collected at various depths, and to monitor for fecal-coliform bacteria, chlorophyll a, phaeopigment, nitrate, nitrite,

ammonium, orthophosphate, silicate. Secchi disk depth data also is recorded. Generally samples are taken at 0, 10, and 30 meters.

Data can be downloaded, by station, month, and year, in HTML or CSV format, from an interactive Web site (<http://www.ecy.wa.gov/apps/eap/marinewq/mwdataset.asp>).

South Puget Sound Focus Study

Ecology's Environmental Assessment team conducted a Marine Waters Focus Study in the South Puget Sound (fig. 44). This focus study is conducting integrated monitoring and modeling of southern Puget Sound as part of the Puget Sound Marine Environmental Modeling partnership (PSMEM) to investigate ecological processes throughout Puget Sound.

The purpose of the South Puget Sound Focus Study is to evaluate the potential effects of increased nutrients, due to development pressure, on phytoplankton growth, and the associated changes in dissolved-oxygen concentrations. The model used for the South Puget Sound Study area is the Environmental Fluid Dynamics Code (EFDC). The EFDC originated as a Chesapeake Bay water-quality model by the Corps of Engineers in 1994 and has since had modifications by the Virginia Institute of Marine Science. This model simulates hydrodynamics, salinity, temperature, and nutrients in three dimensions.

The focus study has two phases, (1) data collection and analysis of historical data, development of initial hydrodynamic and water-quality models of South Puget Sound; and (2) refinement of the models based on the results of Phase 1 and future data-collection programs.

The field-studies portion of the project included 6 cruises from 1998 to 2000 to examine hydrographic and biological characteristics, and to provide data for model input, calibration, and validation.

Reports, results, and a summary of the project are available on the project's Web site (http://www.ecy.wa.gov/programs/eap/mar_wat/focused_south.html).

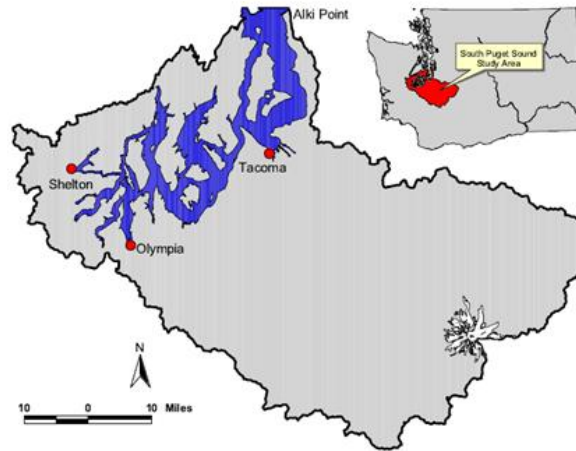


Figure 44. Map of South Puget Sound Focus Study Area, Washington, including major cities (red dots) for spatial reference. (Albertson and others, 2002).

Puget Sound Regional Synthesis Model (PRISM) Cruises: Marine Waters Monitoring, University of Washington

Puget Sound Regional Synthesis Model (PRISM) is a University of Washington initiative. Since 1998, PRISM cruises have been conducted annually to approximately 40 stations within Puget Sound (fig. 45). The cruises are designed to collect a synoptic snapshot of the oceanographic conditions in Puget Sound in early summer (June) and winter (December). The PRISM cruises are building a time series of data that can be used to investigate Puget Sound oceanography and interannual variation.

Standard variables measured on each cruise are temperature, salinity, density, oxygen, chlorophyll fluorescence, light transmission, PAR, and, at some stations, primary productivity. In addition, other measurements have been made on selected cruises.

The standard data from the semiannual PRISM cruises are available for download at the PRISM Cruises Web site (<http://prism.washington.edu/stories/factSheet.jsp?title=PRISM%20Cruises>).

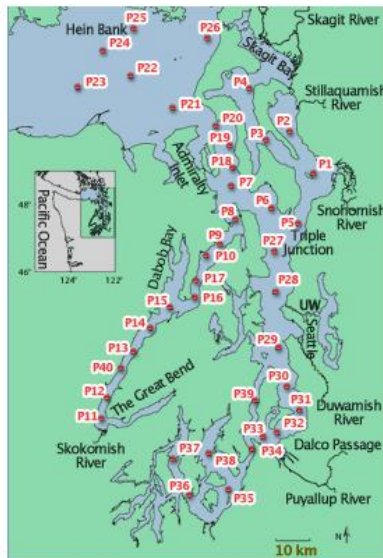


Figure 45. Map showing Puget Sound Regional Synthesis Model (PRISM) Cruise Stations, Puget Sound, Washington (PRISM).

Routine Offshore Water Column Monitoring, King County

King County conducts water-column monitoring at 16 stations that are sampled monthly as part of the Offshore Water Column Monitoring Program. The stations include seven outfalls at three locations (West Point, Renton, and Vashon treatment plants), five ambient at five locations (Point Wells, Point Jefferson, Elliott Bay, Fauntleroy/Vashon, and East Passage), two in inner and outer Quartermaster Harbor, and two new ambient stations in the Duwamish River.

At all stations the water column is profiled in place from surface to depth for salinity, temperature, depth, PAR, chlorophyll (fluorescence), dissolved oxygen, and transmissivity.

Shellfish and Harvest Bed Conditions

Shellfish and harvest-bed condition monitoring efforts in the Puget Sound are done by the Washington State Department of Health (WA DOH).

Washington State Department of Health Shellfish Programs

WA DOH's Division of Environmental Health, Office of Shellfish and Water Protection, conducts Shellfish Programs that include the Biotxin Program, Commercial Shellfish Licensing and Certification Program, Growing Areas Classification Program, and the Recreational Shellfish Program.

The Biotoxin program monitors biotoxins in molluscan shellfish year-round in both recreational- and commercial-harvest areas within the Puget Sound.

The Growing Areas Classification Program monitors and classifies shellfish-growing areas for harvest suitability. The growing area's classification is determined by a three-phase survey process: (1) a shoreline survey, that identifies pollution sources that might impact water quality; (2) marine water sampling to determine fecal-coliform bacterial levels in the water, and (3) analysis of weather conditions, tides, currents, and other factors that may affect the distribution of pollutants in the area.

From these surveys and analyses for each growing area DOH prepares annual reports that include maps with the growing-area classifications and a Threatened Shellfish Areas List for each county. DOH also offers an interactive mapping application on their Web site that shows public (recreational) beaches closed to harvesting due to biotoxins or pollution (<http://ww4.doh.wa.gov/scripts/esrimap.dll?name=bioview&Cmd=Map&Step=1>).

Freshwater Quality

Monitoring efforts of fresh-water quality in the Puget Sound Basin are done by Ecology, the USGS, and the USEPA.

NAWQA: National Water Quality Assessment, U.S. Geological Survey

The USGS began its National Water Quality Assessment (NAWQA) program in 1991 to systematically collect chemical, biological, and physical water-quality data across the nation. Intensive data collection for the Puget Sound Basin began in 1996.

Data are available through 2007 for the Puget Sound Basin and include chemical concentrations in water, bed sediment, and aquatic-organism tissues for about 2,100 chemical constituents; site, basin, well, and network characteristics with many descriptive variables; daily stream-flow information for fixed sampling sites; ground-water levels for sampled wells; surface-water sites and wells; nutrient samples, pesticide samples, and volatile organic compound (VOC) samples; samples of bed sediment and aquatic-organism tissues; and biological-community data for fish, algae, and invertebrate samples.

Assessments are not limited to a specific geographic area or water-resource problem at a specific time. Therefore, the findings describe the general health of the total water resource (Clark and others, 2004). NAWQA studies focus on streams and ground water. Lakes, reservoirs, estuaries, and coastal areas are monitored only in a few selected areas for specialized studies (Gilliom and others, undated).

Attributes for the NAWQA site locations in Washington State include a 15-digit station identification number and place name. The 142 stations in the Puget Sound Basin include ground-water (GW) and surface-water (SW) sites (fig. 40). The dataset is in ESRI shapefile format, a state-plane projection, and is 980 KB (<http://wa.water.usgs.gov/projects/pugt/>).

National Water Information System (Real-Time Streamflow-Gaging Station Data), U.S. Geological Survey

The USGS in Washington State collects data for approximately 300 streamflow, reservoir, water-quality, meteorological, and ground-water sites, of which, about 240 have satellite telemetry for real-time data, and another 20 have different communications equipment for near-real-time data. There are 142 of these water-information system sites in the Puget Sound Basin (fig. 40). The spatial data for the sites are in ESRI shapefile format represented by point features in a state-plane projection and total 75 KB for the Puget Sound Basin, 4 MB for the entire United States.

Real-time data can be downloaded from the Web in table format and then joined to the geospatial data (<http://waterdata.usgs.gov/nwis/rt>). The types of data collected generally fit into the broad categories of surface water and ground water. Surface-water data, such as gage height (stage) and streamflow (discharge), are collected at major rivers, lakes, and reservoirs. Ground-water data, such as water level, are collected at wells and springs. Water-quality data also are available for both surface-water and ground-water. Examples of water-quality data collected include temperature, specific conductance, pH, nutrients, pesticides, and volatile organic compounds.

U. S. Geological Survey Lake and Reservoir Water Quality

As part of the National Water Information System, the USGS provides water-quality sample locations and parameters for a variety of lakes, reservoirs, and mines across the United States, including Washington State. Water-quality data for Washington State were downloaded by the WA DNR on June 6, 2005, from the USGS Water Quality Samples for Washington Web site (<http://nwis.waterdata.usgs.gov/wa/nwis/qwdata>).

In all, 736 water-quality sample locations are represented for Washington State as well as 58,039 database records of water-quality parameters that were collected between 1970 and 2003. More than 500 different water-quality parameters are included in the dataset; however, no sample location was sampled for all of the parameters collected. Parameters ranging from “water temperature” to “Antimony, bed sediment smaller than 2 millimeters, wet sieved (native water), total digestion, dry weight, micrograms per gram” were collected.

Of the 736 water-quality sample locations, 472 are within the Puget Sound Basin (fig. 46). The ESRI geodatabase contains point-data feature classes of the samples and a table with the sample data. The database is 8.75 MB and is in a state-plane projection.

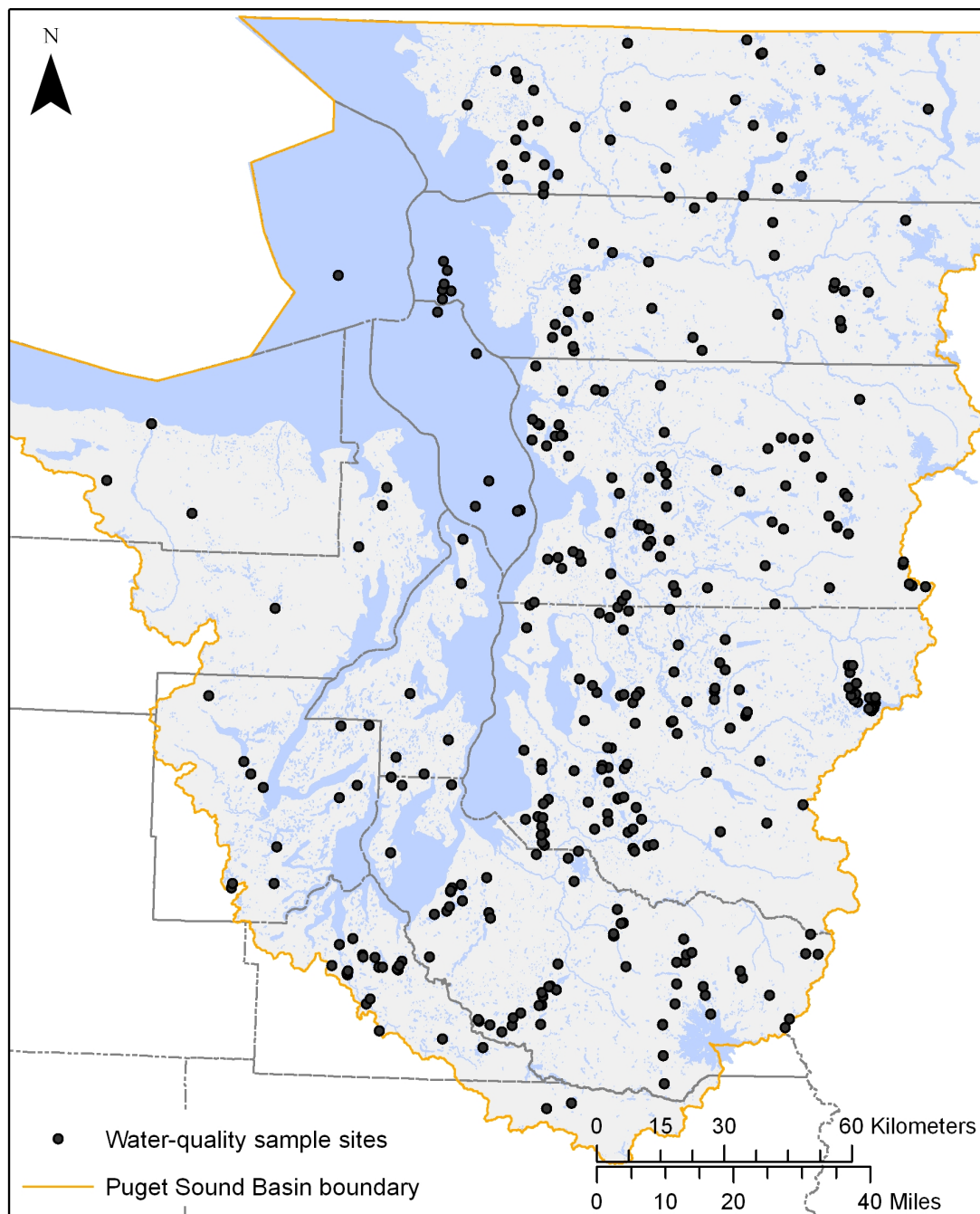


Figure 46. Map of U.S. Geological Survey lake and reservoir water-quality sample sites in the Puget Sound Basin, Washington.

EMAP Freshwater Monitoring: Wadeable Streams

The Wadeable Streams Assessment (WSA), part of EMAP, directed by the USEPA, is a survey of the biological conditions of wadeable streams (shallow enough to sample without the use of boats) throughout the United States. The WSA reports on four chemical indicators, phosphorus, nitrogen, salinity, and acidity; and four physical condition indicators, streambed sediments, instream fish habitat, riparian-vegetation coverage, and riparian disturbance.

Wadeable-stream site data in the Puget Sound Basin and in western Washington (fig. 47) were collected between 2000 and 2003. The data are in ESRI shapefile format in a GCS. Wadeable Streams Assessment data is available from the USEPA's STORET Data Warehouse online at http://iaspub.epa.gov/storpubl/DW_home.

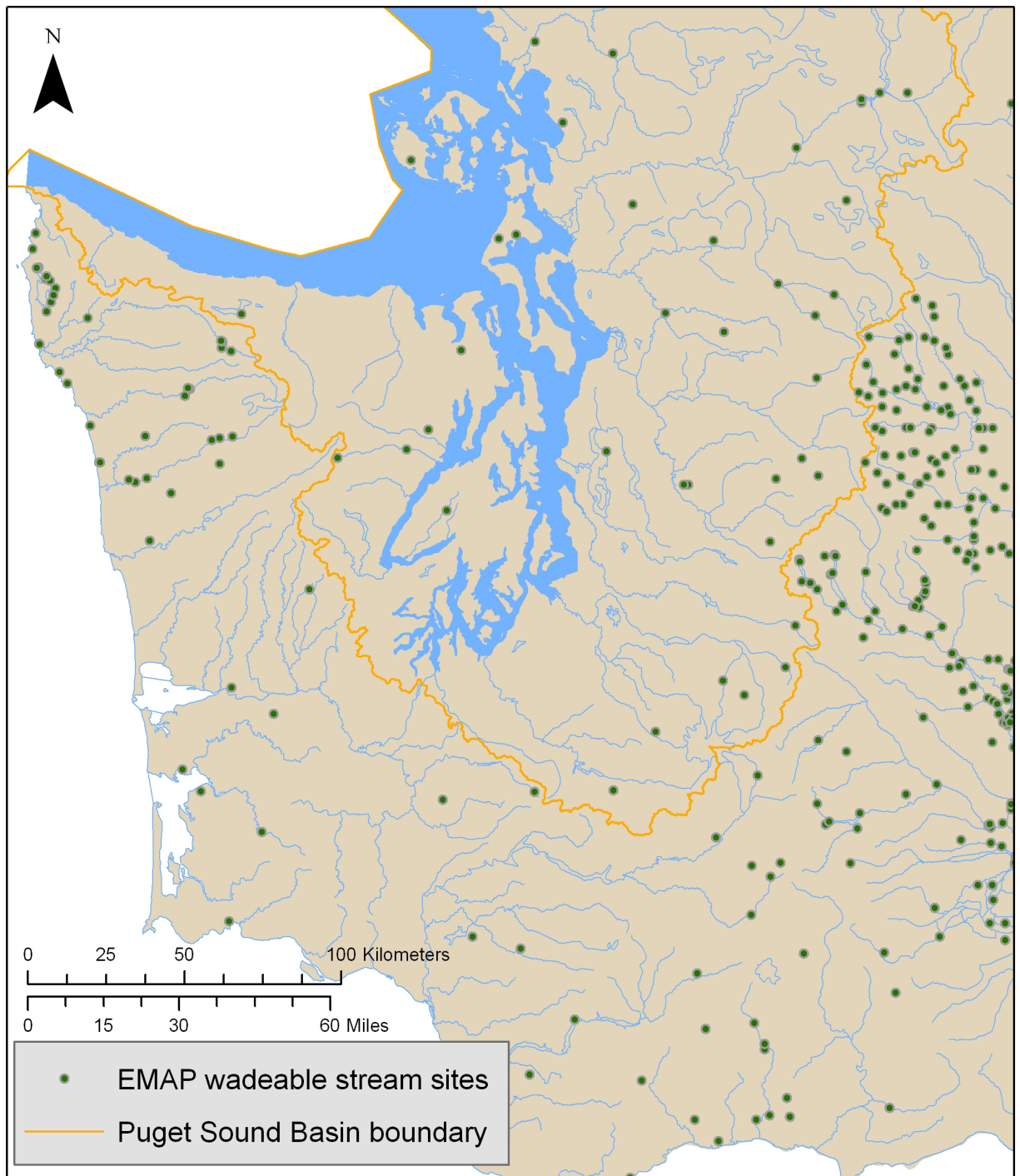


Figure 47. Map of Environmental Monitoring and Assessment Program Wadeable Stream Assessment Sites, Puget Sound Basin, Washington, U.S. Environmental Protection Agency.

River and Stream Water-Quality Monitoring, Ecology

Ecology's Environmental Assessment Program Freshwater Monitoring Unit has done water-quality monitoring of streams and rivers throughout Washington since 1959 (fig. 48).

Monitoring locations include long-term (or "core") stations and basin stations. Core stations are monitored every year to track water-quality trends, assess interannual variability, and collect current water-quality information. Core stations generally are near the mouths of major rivers, below major population centers, where major streams enter the State, or upstream from anthropogenic disturbance on water quality. Basin stations are monitored for one year only to collect current water-quality information. Basin sites are selected to support the wastewater-discharge permitting process, total maximum daily load (TMDL) assessments, and other site-specific needs (Hallock, 2007).

Parameters measured include temperature, pH, conductivity, dissolved oxygen, turbidity, total suspended solids, fecal-coliform bacteria, ammonia, nitrate-nitrite, total nitrogen, total phosphorus, soluble-reactive phosphorus, and stream flow.

Since 1993, the monitoring also has included the assessment of stream biological health through the evaluation of stream insects (benthic macroinvertebrates). Since 2001, the measurement of stream and air temperature every 30 minutes at most monitoring station from June through September was added to the water-quality monitoring program.

The monitoring data are summarized into a Water Quality Index (WQI). This, in turn, contains less information than the raw data. An index is most useful for comparative analysis and general questions.

Monitoring data are available online and may be downloaded in .txt format. Annual reports also are available, beginning in 1991, and include information on the stream-monitoring program in detail (for example, monitoring methods), as well as quality-control evaluation for the preceding year. In addition, special reports that include water-quality assessments, trend analysis, and summaries of water-quality results by region are available online at

http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html.

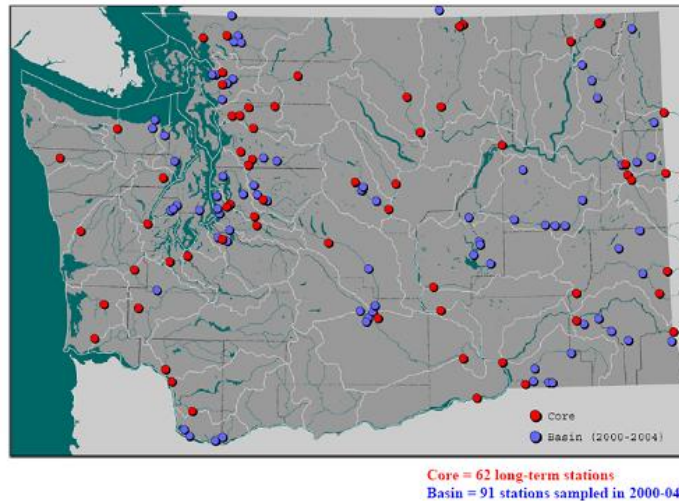


Figure 48. Map of regions, watersheds, and recent stream-monitoring stations by the Washington State Department of Ecology.

River- and Stream-Flow Monitoring, Ecology

The Stream Hydrology Technical Coordination Team (SH-TCT) of Ecology's Environmental Monitoring and Trends Section provides flow information in support of several statewide instream and out-of-stream planning and management efforts, including watershed planning, flood-plain management, and ambient fresh-water monitoring studies. Flow measurements and continuous stage records are archived in a stream-flow database at Ecology's Headquarters in Olympia, Washington.

The Ecology stream-flow stations include three types: telemetry, stand alone, and manual stage-height station types. The telemetry stations log stage height every 15 minutes and transmit the data to Ecology Headquarters. These stage-height data are automatically imported into the streamflow database and published on Ecology's Web site. The stand alone stations log data every 15 minutes and are downloaded periodically, typically once a month. The data are then imported into the database manually and automatically published on the Web. Manual stage-height stations do not produce a continuous record of data, but are the measurement of a single point in a series of periodic gaging station readings.

Ecology's streamflow data are available online through Ecology's Statewide Flow Monitoring Network. All flow stations, with HTML charts and tables of recent 7-day data and current water-year data, can be accessed at Ecology's Web site

(<https://fortress.wa.gov/ecy/wrx/wrx/flows/regions/state.asp>).

Water Temperature Assessment in Washington State, Ecology

Ecology scientists conduct a broad range of technical studies on temperature-related issues in rivers and streams. These projects include thermal infrared (TIR) and color-video aerial surveys, TMDL studies, water-quality standards implementation, and plans for stream improvement. Thermal infrared and color-video aerial surveys can be viewed online at the Water Temperature Assessment in Washington State Web site (<http://www.ecy.wa.gov/apps/watersheds/temperature/index.html>).

Lake Water Quality Monitoring, Ecology

Ecology's Lake Water Quality Assessment Program monitored lakes from 1989 to 1999 with funding from the Federal Clean Lakes Program. On average, 60 lakes were monitored annually. Ecology staff would visit each lake in the spring or early summer and again in late summer while volunteers collected data every two weeks.

Parameters sampled included temperature, pH, conductivity, and dissolved-oxygen profiles, chlorophyll, total nitrogen, and total phosphorus. At selected lakes, hardness, turbidity, total suspended solids, and fecal-coliform bacteria also were monitored. Volunteers monitored surface temperature and Secchi disk depth and provided general information and observations about the lakes they monitored. Volunteers kept an eye out for Eurasian milfoil and zebra mussels during data collection, as well. Reports and associated data are available from the Ecology Web site in PDF format (http://www.ecy.wa.gov/programs/eap/lakes/wq/lake_list.html).

Lake-specific studies were carried out in 1998 and 1999 at approximately 20 lakes where more intensive sampling was done. Additional data gathered for the lake-specific studies included biology, habitat, watershed, and use characteristics. Data and recommendations for individual lakes are available from the Ecology Web site in PDF format (http://www.ecy.wa.gov/programs/eap/lakes/wq/lake_studies.html).

Lakes in Washington were sampled in 2007 as part of a National Lakes Survey in order to report on the ecological health, water quality, and recreational value of the Nation's lakes. For this effort, 30 lakes were selected randomly in Washington and were sampled during summer 2007. The USEPA funded the survey, and Ecology staff did the water-quality sampling, habitat assessments, and other data collection.

The following water-quality indicators were sampled at each lake for the National Lakes Survey.

- Trophic Indicators: lake profiles (pH, conductivity, temperature, and dissolved oxygen), water-quality chemistry and nutrient concentrations, chlorophyll *a*, Secchi disk depth, turbidity, and color.
- Ecological Integrity Indicators: sediment diatoms, phytoplankton, zooplankton, shoreline physical-habitat conditions, and macroinvertebrates.
- Recreational Indicators: pathogen indicator (enterococci bacteria), algal toxin (microcystins), and sediment mercury. Data is not yet available for the National Lakes Survey, and a final report is due out in 2009.

Land-based Sampling

Terrestrial-monitoring efforts in the Puget Sound Basin include programs managed by the USFS, USDA, and the USGS.

Forest Inventory and Analysis (FIA) Monitoring Sites, USFS

Forest Inventory and Analysis (FIA) program collects, analyzes, and reports information on status and trends of America's forests. FIA is run by the USFS and State partnerships (Forest Service, 2005).

The FIA is a collection of related surveys focused on different aspects of forested ecosystems, including forest monitoring (tracks status and trends in forest extent, cover, growth, mortality, and removals), ownership, timber production, and utilization studies (quantities of wood removed during a harvest). The program also projects 10- to 50-year future scenarios of forest trends and overall health (Forest Service, 2005).

FIA plots in the Puget Sound Basin (fig. 49) include data from the FIA Western Washington (FIAWW) and Region 6 Pacific Northwest (R6), data inventories. The FIAWW dates of inventory are 1988-1990, have a 2.4-mile density-sample grid for plot selection, and include timberland only. The R6 dates of inventory are 1993-97, have a 1.7-mile (3.4-mile in wilderness) density-sample grid for plot selection, and include all forest land (PNW-FIA, 2005). The FIA plot location data is in ESRI shapefile format, includes a PLOT_ID field, and is in a GCS (<http://fia.fs.fed.us/tools-data/docs/default.asp>).

The FIA database is complex, with data integrated from several different surveys, sources, and versions. Guides and user manuals for the FIA database are available online. The Pacific Northwest

(PNW) FIA Integrated Database (IDB), Version 2.0 is now available on a CD (more than 900 MB). The IDB is in Microsoft Access 2000 format and includes the R6 and FIAWW inventories (<http://www.fs.fed.us/pnw/fia/publications/data/data.shtml>). Metadata tables (tree species, counties, survey unit, owner) can be queried from the IDB Version 2.0 and linked to the inventory data tables using the PLOT_ID field (PNW-FIA 2005) for mapping and analysis purposes.

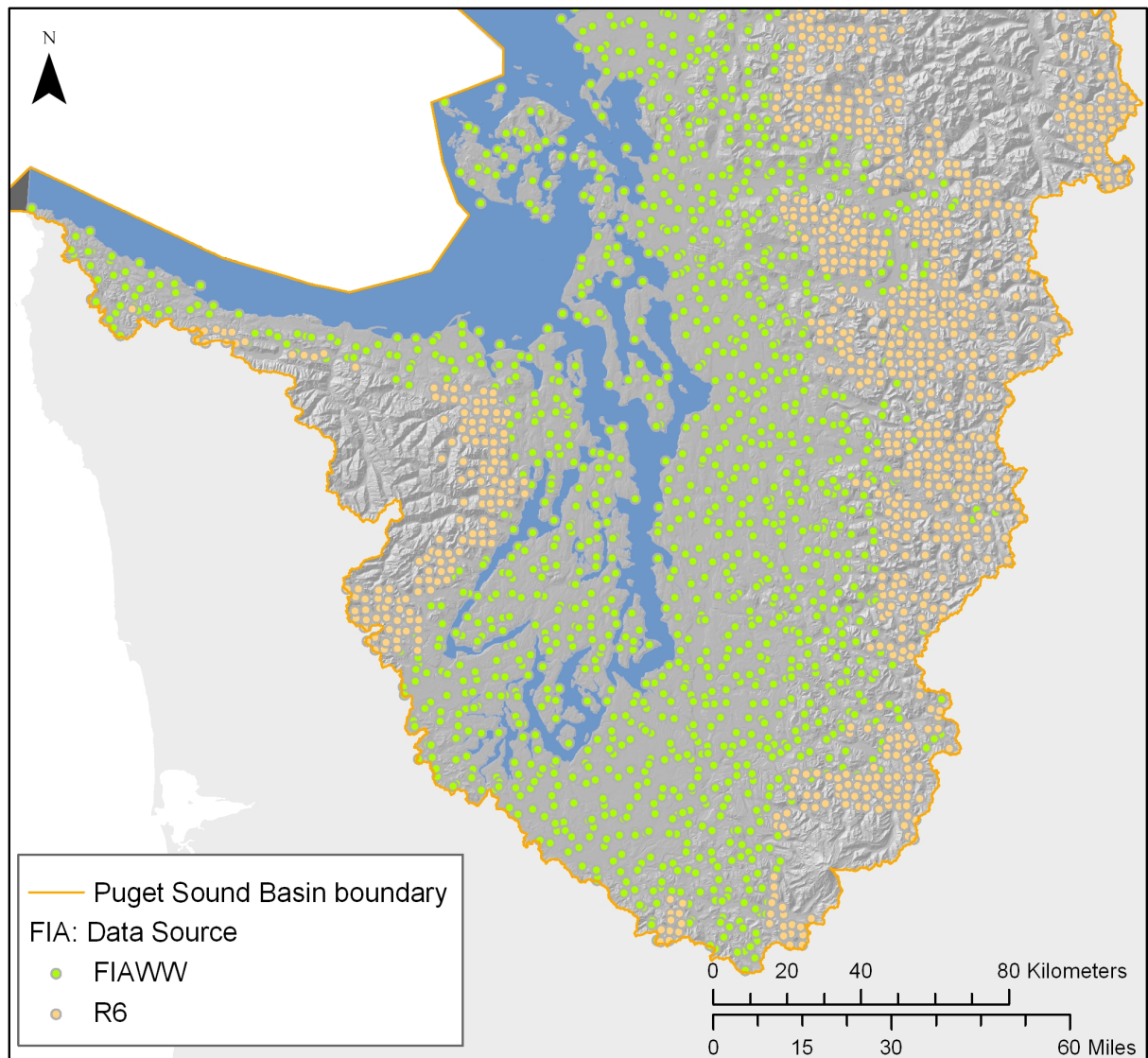


Figure 49. Map of Forest Inventory and Analysis Western Washington (FIAWW) and Pacific Northwest Region 6 Forest Inventory and Analysis (FIA) plot locations in the Puget Sound Basin, Washington.

Region 6 Ecology Program, USFS

The Regional Ecology program has installed more than 38,000 ocular plots in Washington and Oregon since about 1979 (<http://www.reo.gov/ecoshare/>). These datasets have been used to develop Forest indicator-species lists, plant associations, potential-vegetation (PNV) models, and species-habitat models, as well as to refine definitions of old-growth and to provide baseline data for individual National Forest needs.

Ecology plots in the Puget Sound Basin include data collected on three National Forests (fig. 50). Downloadable data include 23 plots from the Gifford Pinchot National Forest, 456 plots from the Olympic National Forest, and 1,810 plots from the Mount Baker-Snoqualmie National Forest.

In addition to the Web data dictionary, downloadable data include specific plot locations, environmental variables, and percent cover by species. Plot data are in an Access database, with “plotnbr” as the key field linking the three tables provided (plot export, plot visit export, and veg cover export). UTM coordinates provided in the tables can be used to create a spatial coverage.

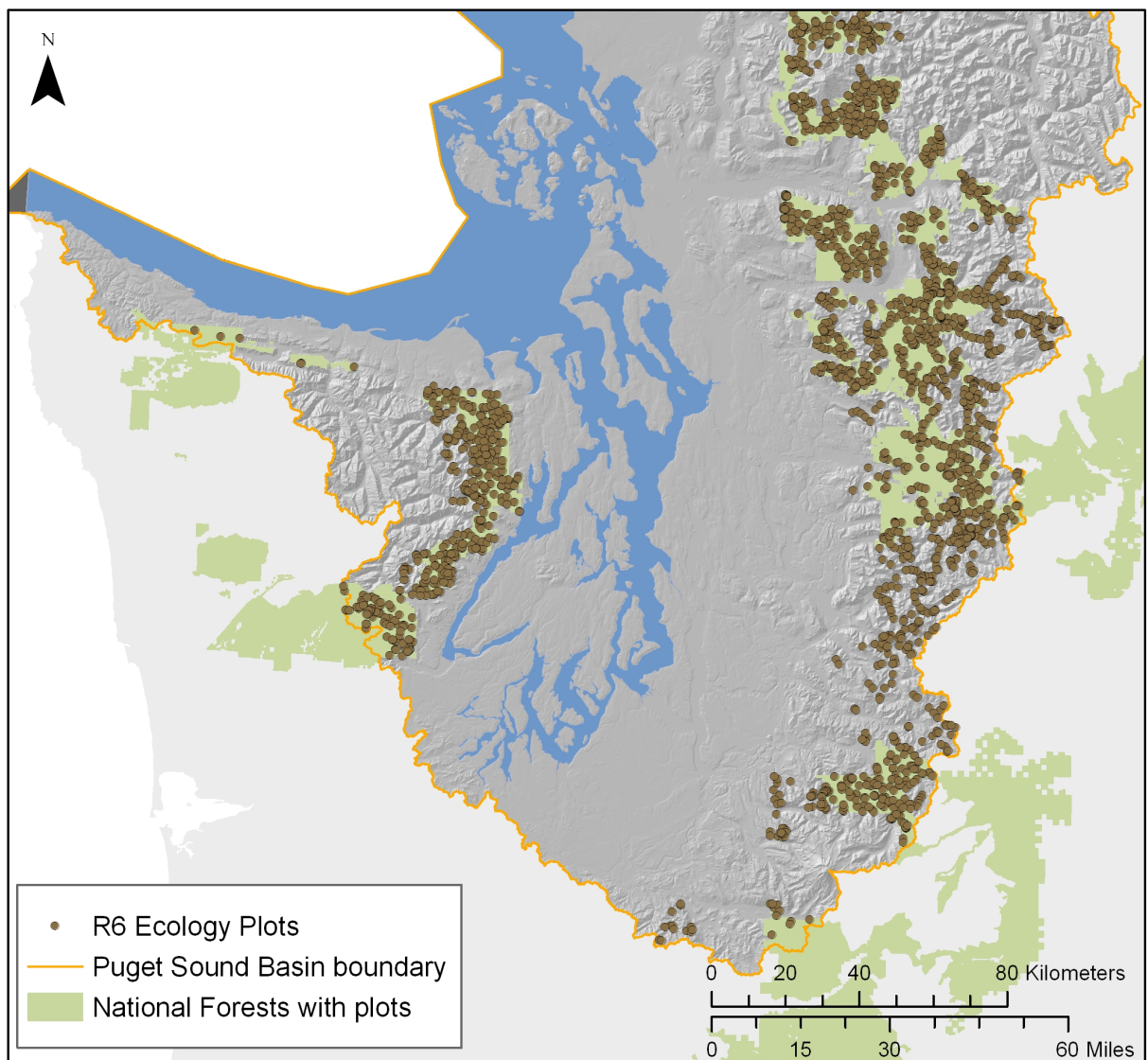


Figure 50. Map of the U.S. Forest Service Region 6 Ecology plots in the Puget Sound Basin, Washington.

Snowpack Monitoring, Natural Resources Conservation Service

The USDA NRCS operates a Snow Survey Program that provides mountain snowpack data and streamflow forecasts for the western United States, including the Puget Sound Basin (fig. 51). Snow Survey Program data is available online at

http://www.or.nrcs.usda.gov/snow/maps/pugetsound_basin_map.html. Data collection has been automated since 1980 to collect snowpack and related climatic data called SNOTEL (SNOWpack

TElemetry). SNOTEL data is available in 7-day summary and in-depth reports and as historical data in tab-delimited files for individual years from 1979 to 2008 (<http://www.or.nrcs.usda.gov/snow/>).

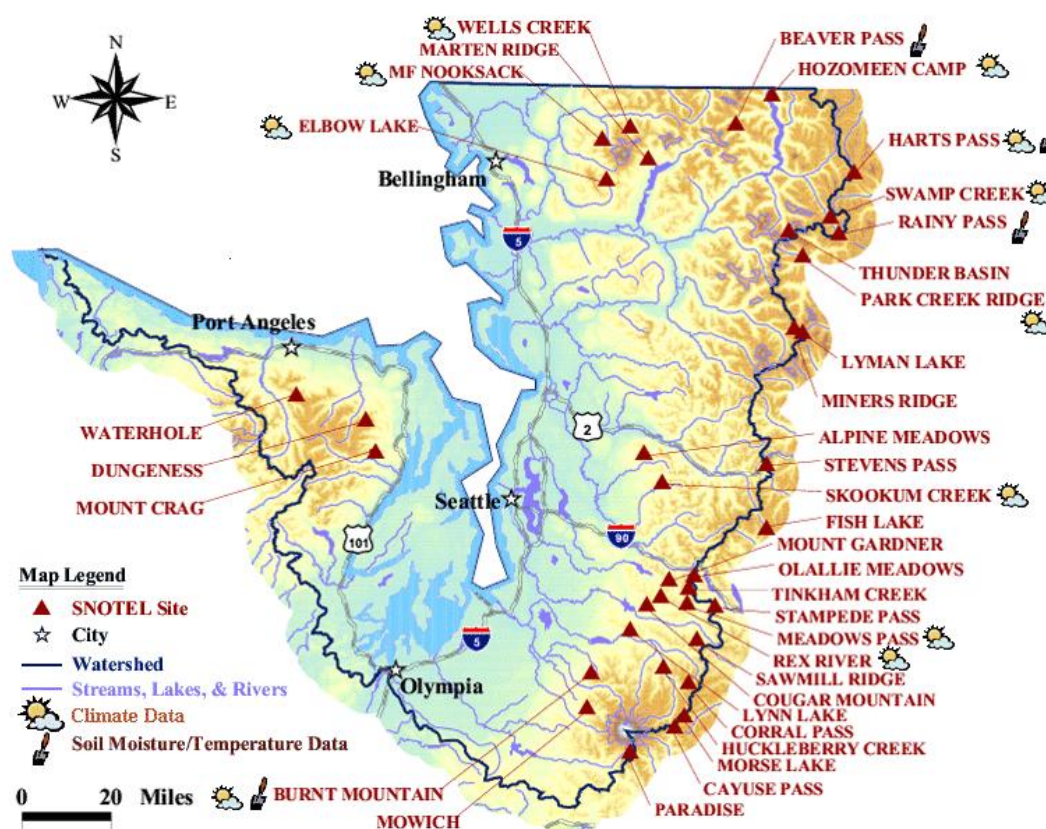


Figure 51. Screen capture of map showing SNOwpack TElemetry (SNOTEL) sites in the Puget Sound Basin, Washington (NRCS).

Glacier Monitoring, U.S. Geological Survey

The USGS operates a long-term program to monitor climate, glacier motion, glacier mass balance (for example, dynamics of accumulation and ablation), and stream runoff. The South Cascade glacier monitoring, in the Puget Sound Basin, is part of a program to establish long-term mass-balance monitoring programs at three glacier basins in the United States, (Gulkana and Wolverine glaciers in Alaska are the others). Data collected are used to understand glacier-related hydrologic processes and improve predictions of water resources and climate change. An example of mass-balance data can be seen in figure 52 of the cumulative mass balance of South Cascade Glacier from the 1950s to 2005 (http://ak.water.usgs.gov/glaciology/south_cascade/index.html).

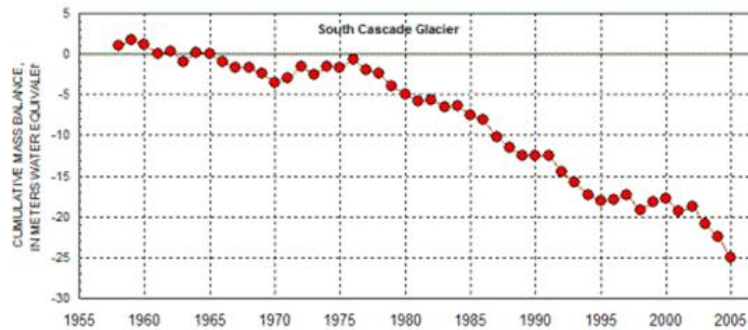


Figure 52. Screen capture of graph displaying the cumulative mass balance in meters water equivalent for the South Cascade Glacier from the 1950s to 2005 (USGS, http://ak.water.usgs.gov/glaciology/all_bmg/3glacier_balance.htm).

Invasive-Plant Species Inventories

In the U.S. and in Washington, no single Federal, State, or local agency regulates invasive plants or compiles inventory data. To evaluate how to develop an integrated landscape-monitoring program, PSILM reviewed overall data collection and management of invasive-plant sites in the Puget Sound Basin as a whole. Then, PSILM focused on a single watershed, the Nisqually watershed (WRIA 11), to evaluate which datasets were available and in what formats.

Invasive-plant species are defined here as those listed by Federal (USDA Animal and Plant Health Inspection Service, 2006) or State agencies (Washington State Department of Agriculture, 2008; Washington State Noxious Weed Control Board, 2008) as noxious or prohibited.

State and County Invasive Plant Datasets

Within the Puget Sound Basin, 13 different county weed-control programs implement the State weed-control law, Chapter 17.10 RCW, and have noxious weed data: Whatcom, Skagit, Snohomish, King, Pierce, Kitsap, Island, San Juan, Thurston, Lewis, Mason, Jefferson, and Clallam counties. These data are not available on the Web; each individual county-weed program must be contacted for information.

WA DNR and WA Parks manage lands in the Puget Sound Basin and have some data on infestations that occur on the State lands that they manage. Ecology's Water Quality Program has additional data on aquatic infestations found as part of aquatic surveys. These data are not available on the Web; each individual State program must be contacted for information.

U.S. Forest Service Invasive-Plant Inventory

To track weed infestations, USFS uses its Invasive Plant Inventory application, a stand-alone module of its Natural Resource Inventory System (NRIS). An application overview is available online (<http://www.fs.fed.us/emc/nris/products/invasives/index.shtml>). The Oracle database links to individual ArcGIS polygons and meets North American Weed Mapping Standards (NAWMA, 2002).

The Olympic, Gifford Pinchot, and Mount Baker-Snoqualmie National Forests manage lands in the Puget Sound Basin and have NRIS Invasive spatial and tabular data available. Spatial data are in a UTM projection. These data are not available on the Web; each individual Forest must be contacted for information.

The Mount Baker-Snoqualmie National Forest also tracks its botany surveys. Spatial and tabular data are available for all complete and intuitively controlled plant surveys conducted from 1990 to present. An Access database contains survey-area information, as well as all vascular plant, bryophyte, and lichen species detected within the survey area by a professionally trained botanist. Areas surveyed range from 0.1 to 712 acres. Spatial data are in a UTM projection. These data are not available on the Web; the forest botany program manager must be contacted for information.

In 2006, the Mount Baker-Snoqualmie National Forest evaluated its NRIS Invasives data, the Region 6 Ecology Program data, and botany-survey data to determine which non-native species were present (Fuentes, 2007). Site and survey data are available for 148 non-native plant species, including 34 species of noxious weeds.

Nisqually Cooperative Weed Management Area (CWMA)

The PSILM has partnered with the Nisqually Cooperative Weed Management Area (CWMA) program in order to evaluate their datasets, with a future goal of studying the effects of invasive-plant species and their management in the Nisqually watershed (WRIA 11).

Because the watershed lies within parts of three different counties, noxious-weed programs in Pierce, Thurston, and Lewis counties maintain datasets on invasive-plant distributions within the watershed. Other land managers or owners maintain invasive-plant datasets, as well. Two data managers (Pierce County Noxious Weed Program and Gifford Pinchot National Forest) verified that their datasets meet North American Weed Mapping Standards (NAWMA, 2002).

The sections below summarize the datasets that PSILM has reviewed. Other datasets maintained by the Lewis County Noxious Weed Program, Nisqually Indian Tribe, Nisqually National Wildlife

Refuge, Pack Forest, Nisqually Land Trust, The Nature Conservancy, Tacoma Power, Thurston County Conservation District, and other agencies exist in electronic or paper formats, but have not yet been evaluated.

Pierce County Invasive-Plant Data

The Nisqually CWMA is run by the Pierce County Noxious Weed Program and its program coordinator. Knotweed-distribution data on the Nisqually River's mainstem were collected by using GPS units during rafting, road, or river-walk surveys in 2007. At each patch of knotweed encountered along the survey information was collected including the species of the knotweed, infestation size, stand density, stem count, phenology, proximity to the river, and treatment method. Waypoints also were taken at each patch site (fig. 53) for further treatment, monitoring, and analysis. The spatial-location data are in ESRI shapefile format in a state-plane projection. This dataset is available by contacting the weed-program coordinator.

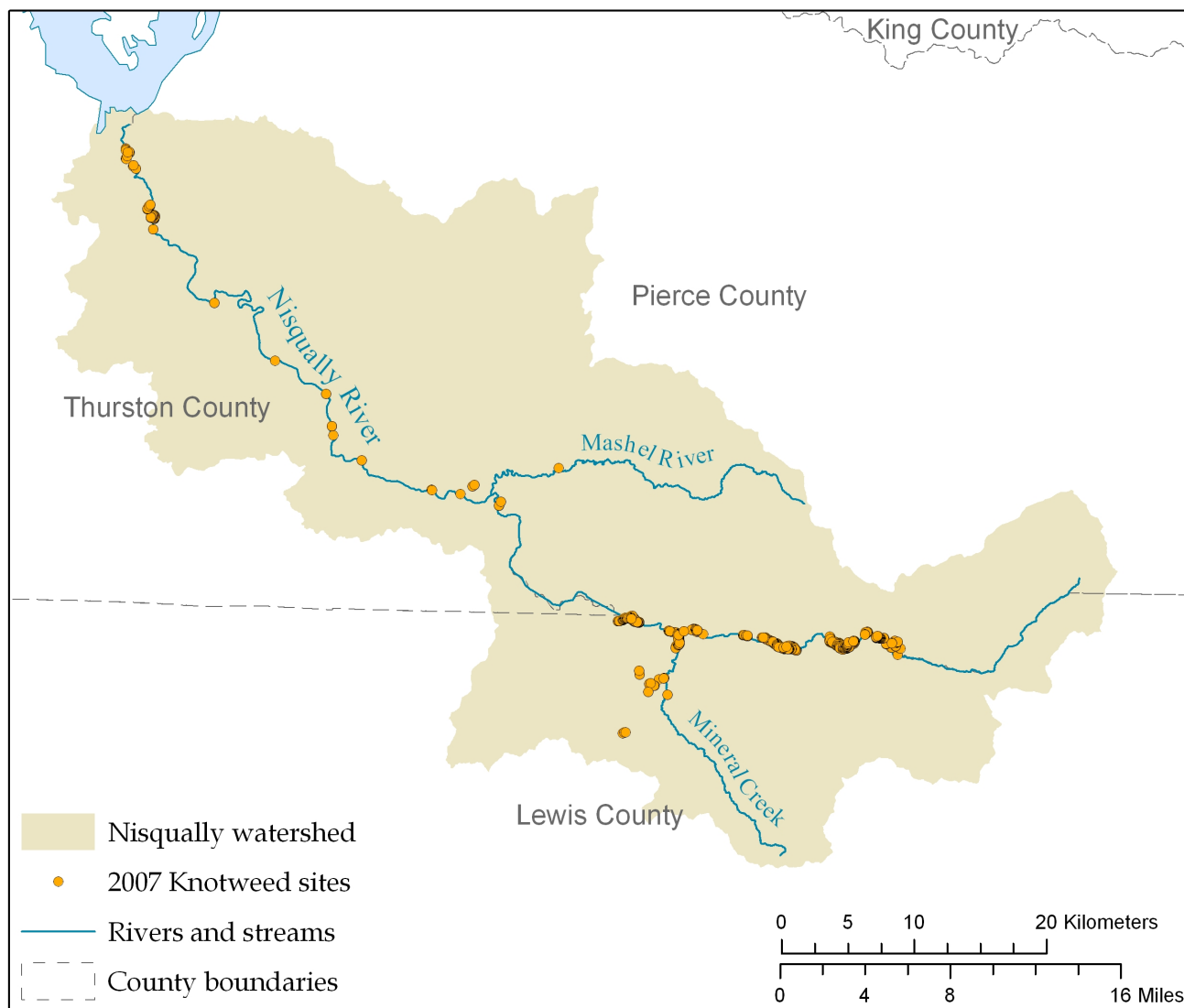


Figure 53. Map of Nisqually CWMA 2007 Knotweed-Survey Sites

Thurston County Invasive-Plant Data

The Thurston County Noxious Weed Control Program monitors for 36 species of noxious weeds that are targeted for control out of a list of 86 weeds designated noxious by the State of Washington. The remaining 50 species have not yet been found in Thurston County, but are surveyed annually for early detection. The weed program is focused on weeds of limited distribution where there is a possibility of eradication and preventing or reducing populations.

The noxious-weed inventory is in point ESRI shapefile format, an unknown projection, and includes weed sites between 1975 and 2007 in Thurston County (fig. 54). The Thurston County data

information is available online (http://www.co.thurston.wa.us/tcweeds/noxious_weeds.htm). Attribute information includes weed type and name, dominance level, status, year, jurisdiction, parcel number if applicable, and a site identification number. This dataset is available by contacting the weed-program coordinator, and a county wide map of weed infestations is available on the Web.

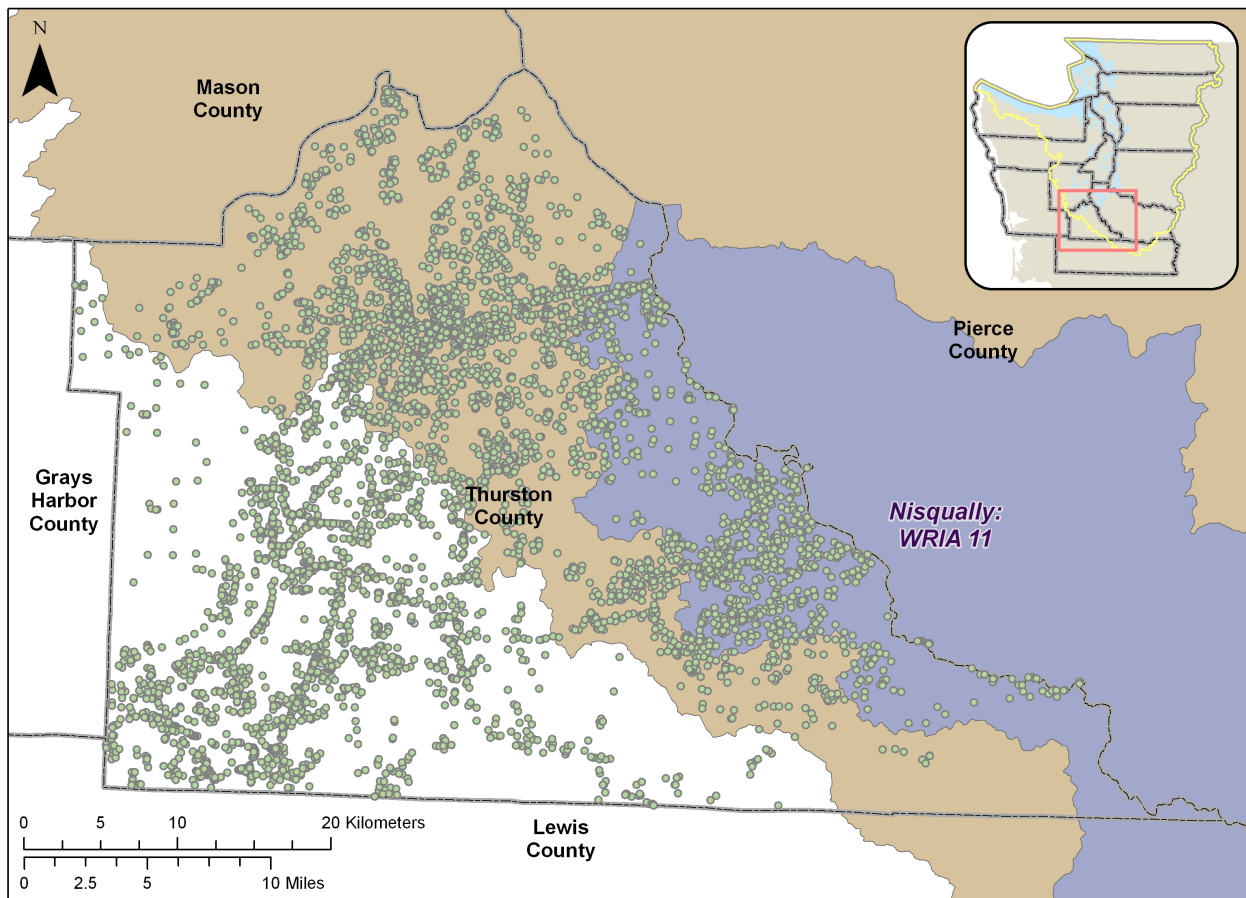


Figure 54. Map of Thurston County noxious weed sites (1975-2007), Puget Sound Basin, Washington.

Mt. Rainier National Park Exotics Inventory

The Mt. Rainier National Park Exotics Inventory includes an Access Databases of exotic-plant control and inventory from 2006. Site Codes include plant-control sites with descriptions. No maps or waypoints are available at this time. The inventory dataset is available by contacting Mount Rainier National Park.

Gifford Pinchot National Forest

The Gifford Pinchot National Forest maintains its noxious-weed sites in the USFS NRIS Invasive Plant Inventory, as described above. These data are not available on the Web; the forest weed manager must be contacted for information.

Conclusions

The data and monitoring efforts cataloged here are intended to be used to discover what knowledge and data are available between ecosystems and at different spatial scales across the Puget Sound Basin. The data sources included can be used to answer questions on conditions, impacts, and changes to the marine and terrestrial systems of the Puget Sound Basin. The data can also be evaluated collectively to gain an understanding for the time and location of monitoring efforts within the Puget Sound Basin and PSILM study area.

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